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A TRIDENT SCHOLAR PROJECT REPORT

NO. 160

A Proposed Model for Late Eocene Paleogeographic Transitions of Western Oregon and Washington Reconstructed from Stratigraphic Relationships, Facies Interpretation, and Paleoecological Analysis of Fossil Assemblages

UNITED STATES NAVAL ACADEMY
ANNAPOLIS, MARYLAND

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER U.S.N.A. - TSPR: no. 160 (1989)	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A PROPOSED MODEL FOR LATE EOCENE PALEOGEOGRAPHIC TRANSITIONS OF WESTERN OREGON AND WASHINGTON RECONSTRUCTED FROM STRATIGRAPHIC RELATIONSHIPS, FACIES INTERPRETATIONS, AND PALEOECOLLOGICAL ETC.		5. TYPE OF REPORT & PERIOD COVERED Final 1988/89 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) John E. Ries		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS United States Naval Academy, Annapolis.		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS United States Naval Academy, Annapolis.		12. REPORT DATE 7 July 1989 13. NUMBER OF PAGES 81
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report)		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Accepted by the U.S. Trident Scholar Committee.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Geology, Stratigriphic Eocene Oregon Washington (State)		

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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U.S.N.A. - Trident Scholar project report; no. 160 (1989)

A Proposed Model for Late Eocene Paleogeographic Transitions of Western Oregon and Washington Reconstructed From Stratigraphic Relationships, Facies Interpretation, and Paleoecological Analysis of Fossil Assemblages

A Trident Scholar Project Report

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USNA-1531-2

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Abstract:

Eocene rifting between the Kula and Farallon plates of western North America resulted in the formation of a string of volcanic islands along northwestern Oregon and southwestern Washington, which were later accreted to the continent. Previously undescribed floral assemblages from these islands reflect a low-level coastal swamp dominated by _Sabalites_ and _Platanophyllum_, backed by higher altitude uplands with lacustrine deposits dominated by _Pinus_, _Picea_, and _Chamaecyparis_. Diversity of one of the assemblages allows a paleoclimate analysis based on foliar physiognomy.

These assemblages apparently correlate with the late Ravenian floral stage in the Pacific Northwest, a period formerly lacking a definitive marine-nonmarine correlation. Furthermore, these strata, assigned to the upper Narizian foraminiferal stage, seem to correlate with the hydrocarbon producing strata of the Mist Gas Field.

Introduction:

Purpose of Investigation:

The Coast Range of northwestern Oregon and southwestern Washington is underlain by an extensive series of submarine and subaerial basaltic lava flows. Overlying these flows are marine sedimentary units of upper Eocene to middle Miocene age. The discovery in 1979 of commercially productive gas reservoirs near Mist, Oregon sparked a renewed interest in the lowermost of these sedimentary units, the source rocks for the hydrocarbons. The presence of fossil leaves in the area as recorded by Warren and Norbisrath (1946), Cameron (1980), and Jackson (1983) suggests that the current depositional model for the upper Eocene Cowlitz Formation is incomplete. The purposes of this thesis are:

1) To analyze the preserved floral assemblages for climatic implications and to postulate a paleoenvironment of deposition;

2) To use the paleoflora and paleofauna to reconstruct the paleogeography of large island bodies adjacent to the depositional basin;

3) To suggest adjustments to the depositional model for the Eocene Cowlitz Formation; and

4) To examine the implications for marine-nonmarine correlations.

Due to the great amount of current stratigraphic revision in the area, several problems in stratigraphic control are encountered. Since previous investigations in the area were not concurrent, problems have been

compounded by changes in zone assignments, changes in stratigraphic nomenclature, and cumulative misidentifications of strata.

Study Area:

The area examined encompasses the greater portion of the Coast Range of northwestern Oregon and a portion of southwestern Washington. However, the stratigraphic interval examined is small compared to the overall extent of the marine deposits within the area. The area under investigation (Figure 1) extends from approximately 45° 40' to 46°30'N and from 123°10' to 123°55'W.

Field Work:

Field work was completed in segments over the summers of 1984, 1986, and 1988. Due to the lush vegetation present in the Oregon and Washington Coast Range, the only exposures are those in roadcuts, railway cuts, and in stream banks. Access is limited to the period from April to September due to the snow cover present the rest of the year. Some exposures are only accessible in late July and August when water levels are at a minimum. Heavy rainfall during much of the year causes significant erosion and slumping in road cuts, leaving stream banks as the only reliable stratigraphic sections in most places. Access to most field areas was by numerous logging roads maintained by Crown Zellerbach and

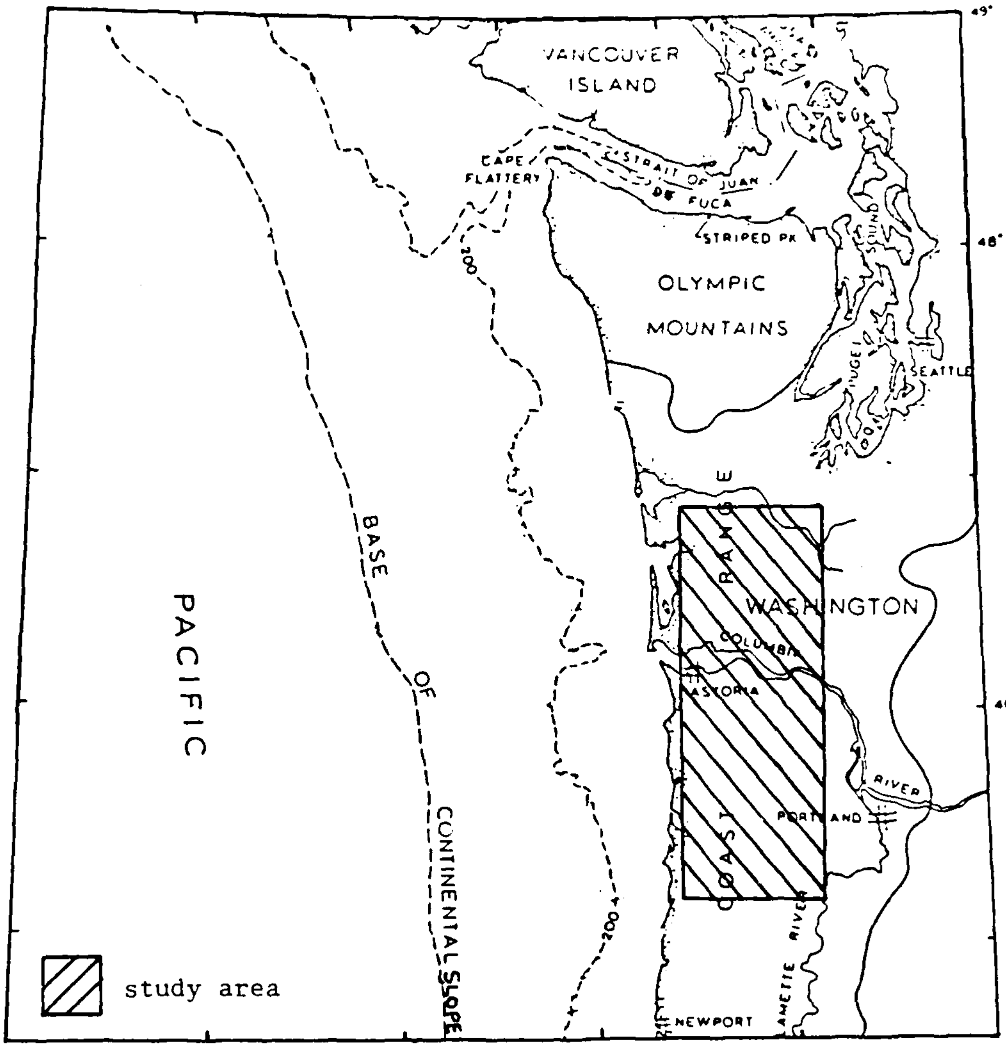


Figure 1. Map of western Oregon and Washington showing area under investigation

Louisiana Pacific.

Macrofossil specimens were collected in the field, and suitable rock samples were selected for palynological analysis in the laboratory.

Laboratory Work:

Macrofossil specimens collected in the field were identified to Genus level when possible. Specimens were assigned numbers indicating location. A portion of the specimens collected for this study will be loaned to the paleobotany section of the Smithsonian Institution, Washington D.C.. The remaining specimens will be stored at Portland State University in Portland, Oregon.

Samples for palynological analysis were macerated, then treated with 25% Hydrofluoric acid solution for seven days. The remaining acid was decanted, and the samples were washed with water twice to remove any traces of acid. Samples were then treated with 20% Hydrochloric acid for a period of four days. Samples were again washed to remove traces of acid. The samples were then stained with basic fuchsin, and mounted on common laboratory slides. The procedures used were modified after Brown (1960).

Foraminiferal samples were removed from the rock by soaking the matrix in kerosene for 24 hours and then boiling until the rock sample dissegregated. Specimens were removed from the matrix under a dissecting scope and

mounted on a standard cardboard specimen slide.

Geologic Setting:

The Coast Range province of northwestern Oregon is dominated by a northward plunging anticlinorium. Tertiary rocks are exposed with the volcanic rocks at the core of the anticlinorium surrounded by a convex north exposure of Tertiary sedimentary strata. Stratigraphically from oldest to youngest, these strata comprise the Tillamook Volcanics, the Cowlitz Formation, the Keasey Formation, the Pittsburg Bluff Formation, and the Scappoose Formation. A correlation chart showing the contemporary stratigraphic units for the central Coast Range and for southwestern Washington is shown in Figure 2.

The Tillamook Volcanics are an accumulation of early to middle Eocene basaltic flow rock, pyroclastics, breccias, mudflows, conglomerates, tuffs, and minor volcanic sediments (Snavely, MacLeod, and Wagner, 1968). The true stratigraphic extent of this formation is unknown since the base is not exposed anywhere in the Coast Range.

In the upper Nehalem River Basin, northwestern Oregon, the oldest exposed sedimentary rocks are those of the upper Eocene Cowlitz Formation. Warren and Norbisrath (1946) divided the Cowlitz Formation into four members on the basis of lithology: a basal conglomerate, a lower shale member, a sandstone member, and an upper

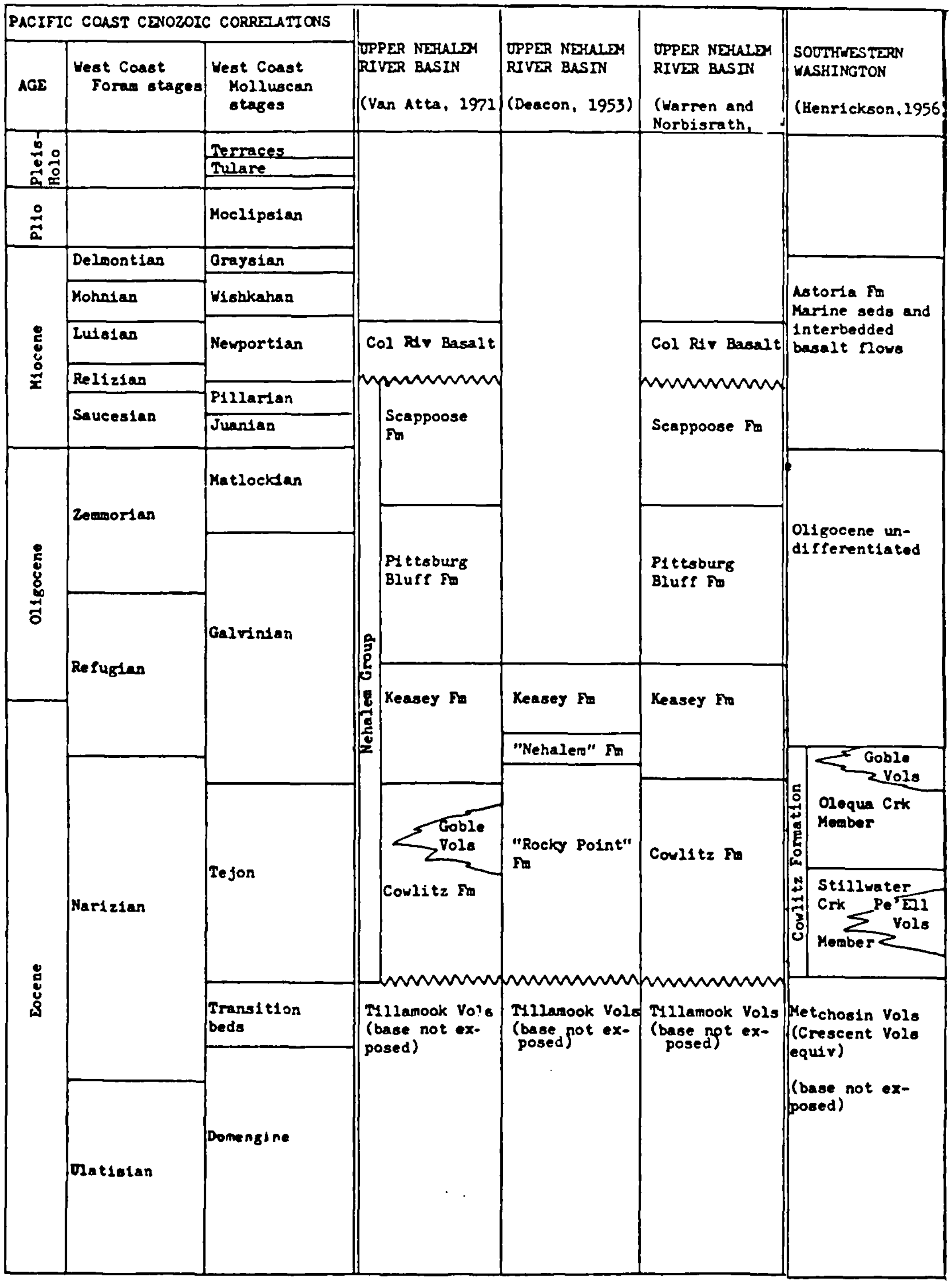


Figure 2. Correlation chart of Tertiary stratigraphic units, western Oregon and Washington

shale member. In a petrographic study of the Cowlitz Formation, Van Atta (1971) revised the stratigraphy into three members: a siltstone member, a sandstone member, and the Goble Volcanics Member. The Cowlitz Formation attains a thickness of as much as 1,000 meters in southwestern Washington (Beaulieu, 1971).

The Keasey Formation unconformably overlies the Cowlitz Formation and consists of up to 2000 meters of deep water tuffaceous, concretionary mudstones and siltstones. Beaulieu (1971) postulates near-shore quiet water deposition for at least a portion of the Keasey Formation.

The Pittsburg Bluff Formation consists of arkosic sedimentary rocks deposited in a shallow marine basin (Jackson, 1983).

The Scappoose Formation consists of arkosic sedimentary rocks deposited as part of a deltaic environment in channels on the eroded surface of the Pittsburg Bluff Formation (Timmons, 1981).

Tectonic Setting:

The geologic history of the Oregon and Washington continental margin is dominated by convergence between the Pacific, Kula, and Farallon Plates and the North American Plate. Oblique convergence occurred during much of the Tertiary, punctuated by periods of head-on convergence (Snavely, 1980). In the middle Eocene, the subduction zone shifted from the site of the present day Cascade Range westward to the present continental shelf. This created a eugeosynclinal basin which accumulated over 7000 meters of Tertiary sediments. Periods of volcanism in the basin caused by rifting between plates created volcanic islands in the basin (Figure 3) (Snavely, 1987). Extension between the Farallon and North American Plates in the latest Eocene caused subsidence of the basin and sediments completely covered the islands.

Paleomagnetic evidence from northwest Oregon indicates a clockwise rotation of $46^\circ \pm 13^\circ$ during the last 44 million years (Magill and Cox, 1981). The volcanic rocks and associated sediments have apparently undergone at least two distinct stages of rotation. The two stages of rotation occurred during the middle Eocene and somewhere between the Miocene and the present (Magill and Cox, 1980).

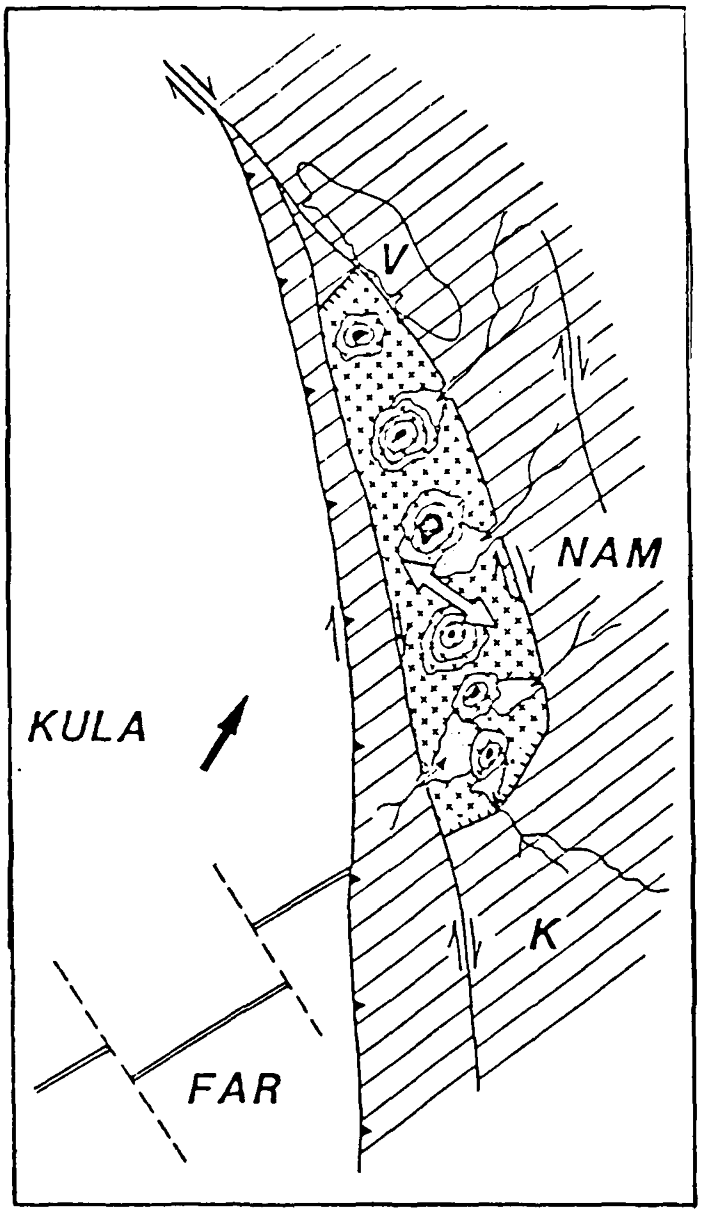


Figure 3. Formation of volcanic islands during period of plate rifting (Snavely, 1987)

Paleogeogeographic Model: Evolution

The first clues to the existence of non-marine sedimentation in western Oregon and Washington were freshwater sediments from southwestern Washington described by Charles E. Weaver (1916a). Associated with these sediments were carbonaceous layers and lignite layers in adjacent brackish-water sediments. The description of these beds as well as several other localized occurrences of lignite and coal (Washburne, 1914; Weaver 1916b), prompted the hypothesis of a westward extension of land. Although such a theory does not seem to have a published description, its earliest occurrence is indicated in the background description of a thesis paper (Souza, 1927). Although extremely vague, the descriptions indicate that a peninsula "first appeared as a point projecting from the land mass to the south, and gradually extended into the Pacific embayment to the north."

Weaver (1937) continued his investigation for evidence to support this hypothesis, examining several large coal deposits in western Washington, as well as conducting intensive investigations of the Tertiary marine sediments and faunal relationships. Eventually, he concluded the existence of a gulf open to the ocean on the south, stretching through Oregon and Washington (Weaver, 1945). He proposed a diastrophic movement at

the beginning of the Eocene as the mechanism for a north-south axial upwarp which produced the "Cowlitz-Arago" Gulf (Figure 4). He suggested a possible comparison to the contemporary Gulf of California. Weaver (1945) indicated that this gulf accumulated approximately 8000 feet of marine sediments which thinned toward the west as the water shallowed on the fringes of the upwarped lava.

The first challenge to Weaver's work came from Snavely and Wagner's (1963) reconstruction of Tertiary paleogeography in Oregon and Washington. The model for the late Eocene (Figure 5) suggested a cluster of islands around 45° Latitude and one small island occupying the region near the Nehalem River Basin. Southwestern Washington was considered unrestricted, open marine deposition.

The last modifications to Weaver's work came from R.J. Dott's (1966) examination of the Eocene deltaic complex at Coos Bay, Oregon. After an extensive analysis of the various lithofacies and a reconstruction of paleocurrents in the delta, he concluded that Weaver's hypothesis was erroneous. He argued that a gulf oriented in a north-south direction as proposed by Weaver would affect the deltaic processes to such a great degree that the dominant westward paleocurrents which he observed would be highly unlikely. Instead, he proposed a paleogeographic model consisting of a broad coastal plain

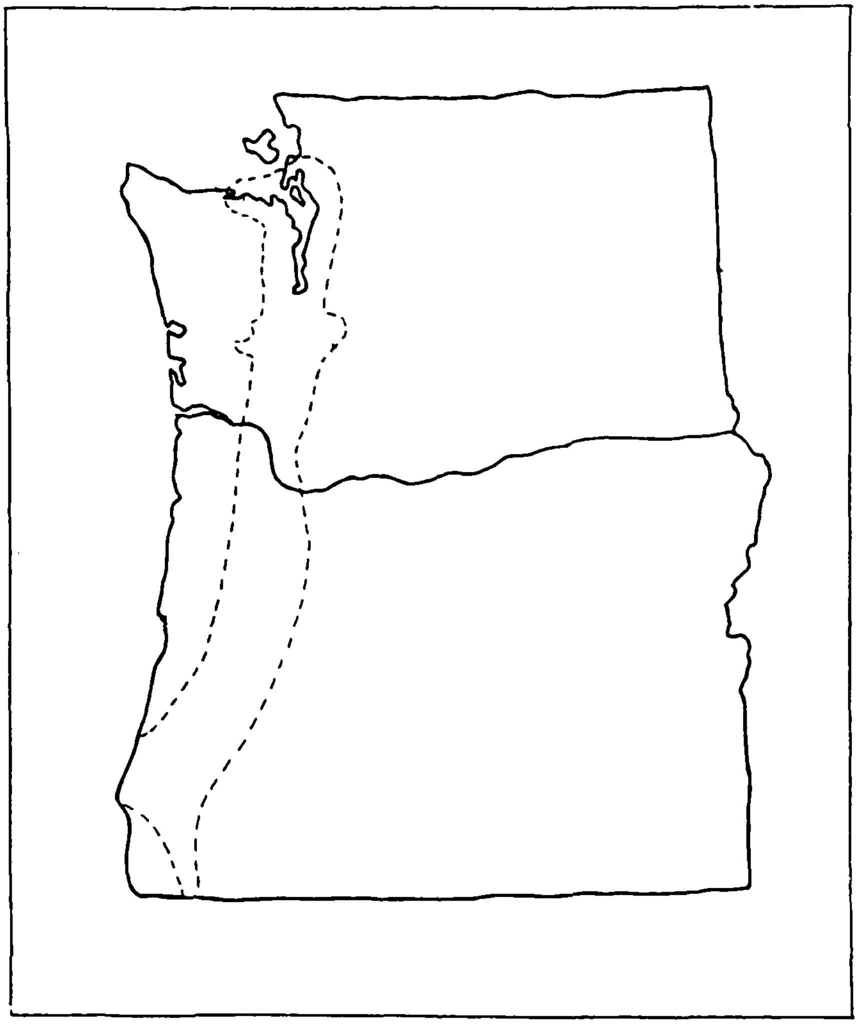


Figure 4. Map showing "Cowlitz-Arago" gulf proposed by Weaver (1937)

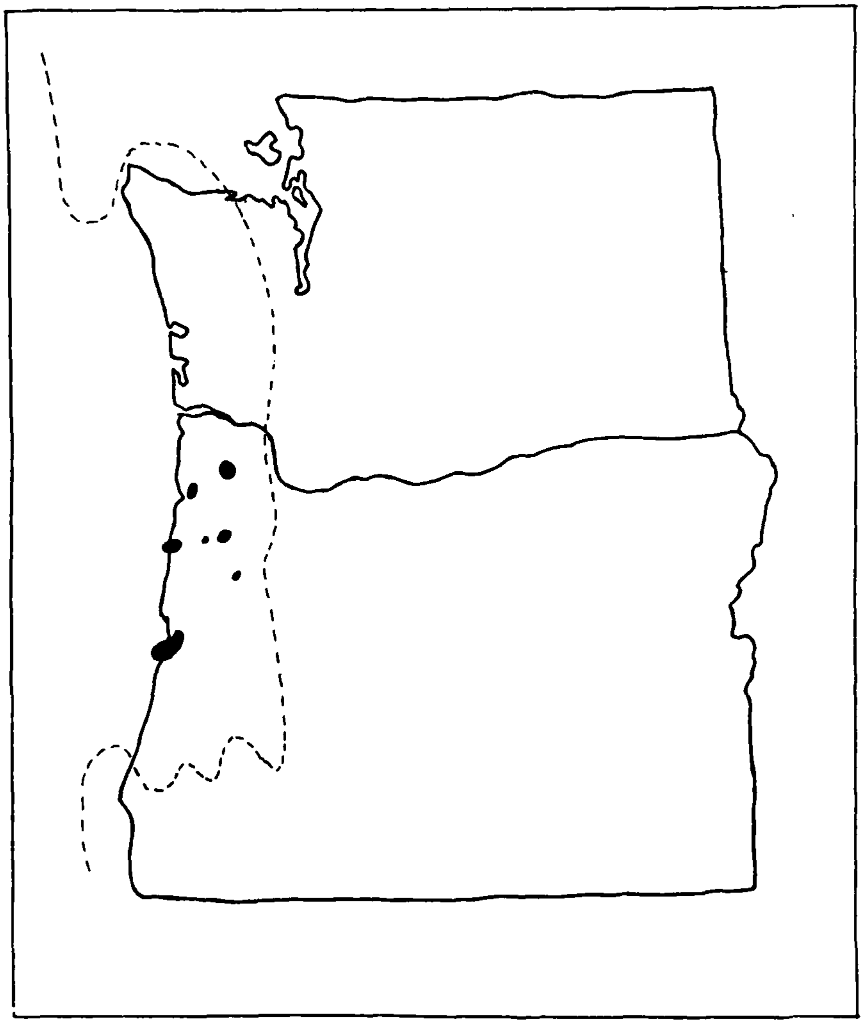


Figure 5. Paleogeographic model of Snavely and Wagner (1963)

backed by the volcanic plateaus of Oregon and Washington (Figure 6). Dott also proposed the existence of scattered volcanic islands in the embayment to account for the freshwater beds described by Weaver. This model remains the current model for late Eocene paleogeography in Oregon and Washington.

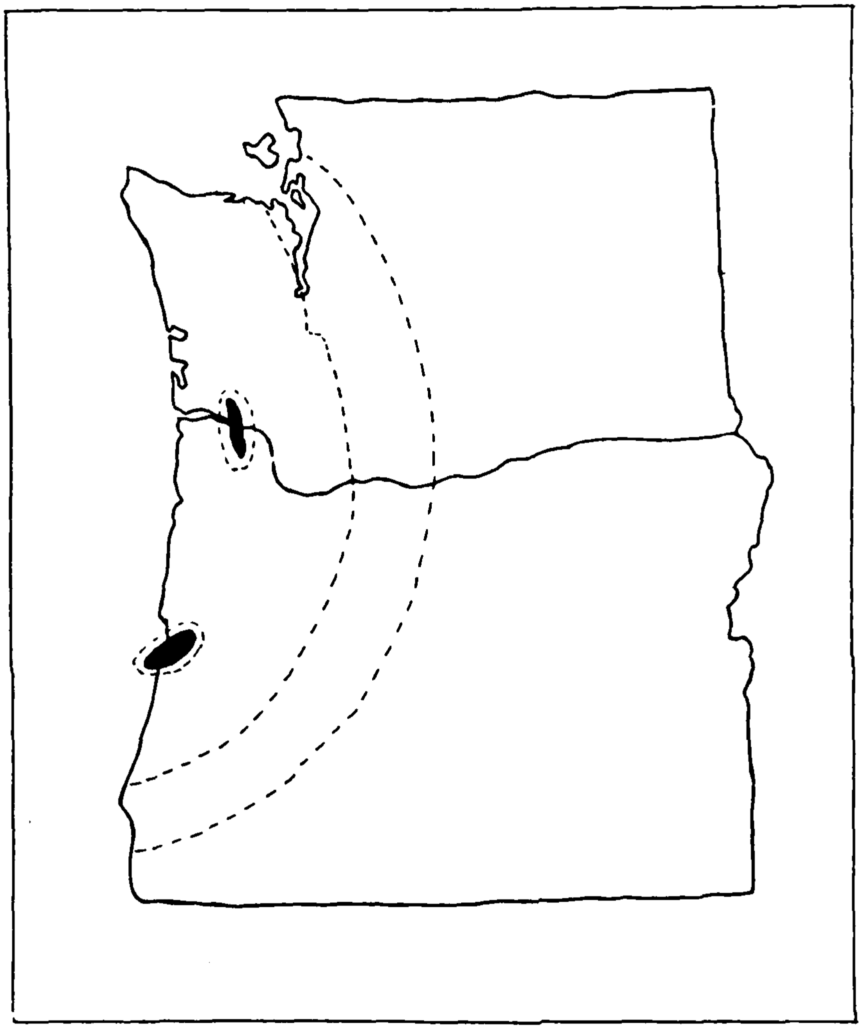


Figure 6. Paleogeographic model of Dott (1966)

Previous Work:

The area of northwest Oregon was first investigated by Diller (1896), who examined the marine formations outcropping near Vernonia. Warren, Norbisrath, and Grivetti (1945) performed the first comprehensive mapping in the area, and later, Warren and Norbisrath (1946) made lithologic and paleontologic observations. Although several graduate students (Timmons, 1981; Jackson, 1983; and Shaw, 1986) later mapped the area on a smaller scale with more attention to detail, only minor changes were made to the original map.

Deacon (1953) attempted to revise the stratigraphy of the Upper Nehalem River Basin, renaming the Cowlitz Formation the Rocky Point Formation, a name which was never formally accepted. Van Atta (1971) made petrographic investigations of the Cowlitz Formation, revising the original stratigraphic divisions of Warren and Norbisrath (1946).

Lithology:

Volcanic rocks in the study area represent two major stages of volcanism on the continental margin. Late Paleocene and early Eocene volcanics are typical of an oceanic spreading center while late Eocene volcanics more closely resemble those typical of oceanic islands and hotspot volcanism.

Primary Volcanism:

The Siletz River Volcanics and the Tillamook Volcanics form the core of the Oregon Coast Range (Warren, Norbisrath, and Grivetti, 1945; Snavely and Baldwin, 1948). Beaulieu (1971) correlates the upper Siletz River Volcanics with the Lower Tillamook Volcanics. These are comparable to the basement volcanics of Washington described as the Metchosin Volcanics (Clapp, 1912) and as the Crescent Volcanics (Snavely and Wagner, 1963). These sequences are geochemically similar to oceanic ridge basalts based on low K_2O concentrations (Snavely, MacLeod, and Wagner, 1968; Snavely, 1987), and can be divided into two categories: tholeiitic and alkalic flows. The oceanic nature of these rocks is substantiated by crustal refraction profiles (Berg, et al, 1966) which show that oceanic crustal velocities are present to about 10 km in depth. A petrologic analysis of pillow basalt samples from Mary's Peak by Loescke (1979) demonstrated the much

greater similarity of these flows to ocean ridge basalts than to island arc tholeiites.

Secondary Volcanism:

The basement volcanics of the coast range were accreted to the continent about 50 million years ago (Snavely, 1987). Volcanic units of the upper Siletz River Volcanics, upper Tillamook Volcanics, and Goble Volcanics suggest that a seamount chain occupied this accreted terrane (MacLeod and Snavely, 1974; Snavely, 1987; Timmons, 1981; Jackson, 1983). The Goble Volcanics are named for the type section of extrusive volcanics exposed near Goble, Oregon.

Ages of these seamount strata suggest that periods of volcanism were differentiated, perhaps suggesting a fragmented terrane environment. Volcanism apparently occurred first at the northern and southern ends of the basin and later at the center (McWilliams, 1980; Duncan, 1982).

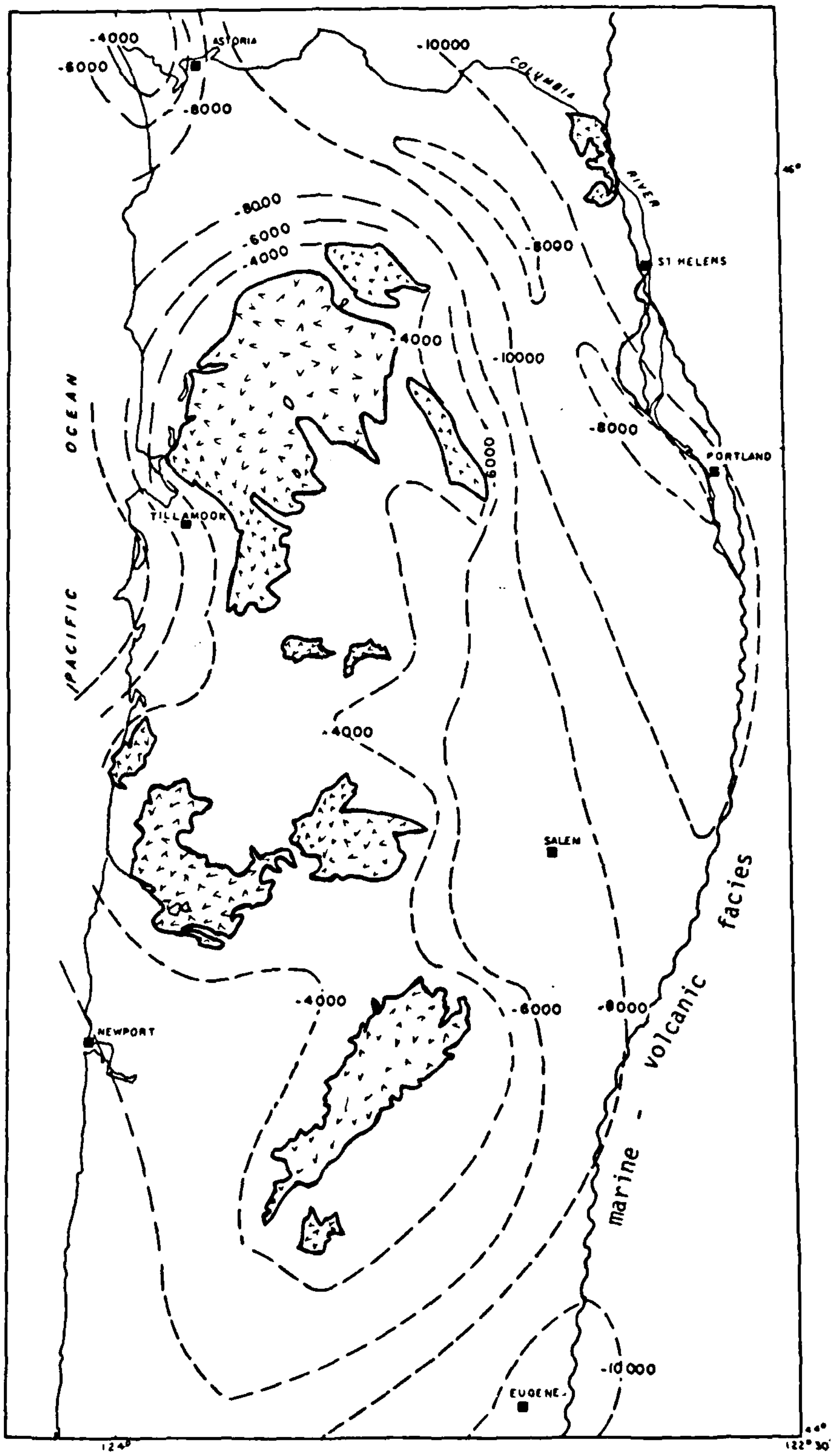
Tillamook and Goble Volcanics:

The different ages of the extrusive rocks involved with the volcanic series make it apparent that subaerial exposure of these islands was not contemporaneous. Therefore, attention was focused on the accreted terrane in northwestern Oregon and southwestern Washington. Maps showing the outcrops of volcanic rocks in Northwestern

Oregon with a superimposed isopach map of Tertiary sediments, demonstrate the extreme variation in sediment thickness, which increases away from these volcanic highs (Figure 7).

Although it is clear that there were two distinct periods of volcanism during the late Eocene, with the Tillamook Volcanic Series underlying the Cowlitz Formation and the Goble Volcanics interfingering with it, some question remains as to the exact stratigraphic placement of individual outcrops (Van Atta, 1971). Since the exact identification of some of these volcanic flows does not greatly affect a reconstruction of these island bodies, an effort to distinguish between these flows will not be made here.

Portions of the Goble Volcanics? are easily recognizable as subaerial in nature. Timmons (1981) describes subaerial flow rocks at Rocky Point, Wolf Creek, the Columbia County Quarry, and near the summit of Green Mountain (Figure 8). Timmons also reported the presence of a laterite, 0.6 m. thick, associated with the flow on the summit of Green Mountain, thus proving the subaerial nature of the flow. Neutron activation analysis of Goble volcanic samples performed by Timmons (1981) showed a distinct geochemical separation from samples of the Tillamook Volcanics. Jackson (1983) in more extensive analysis of volcanic rocks in the area



⊡ volcanic highs

Figure 7. Isopach map of Tertiary sedimentary strata showing exposures of Eocene volcanic rocks (Newton, 1976)

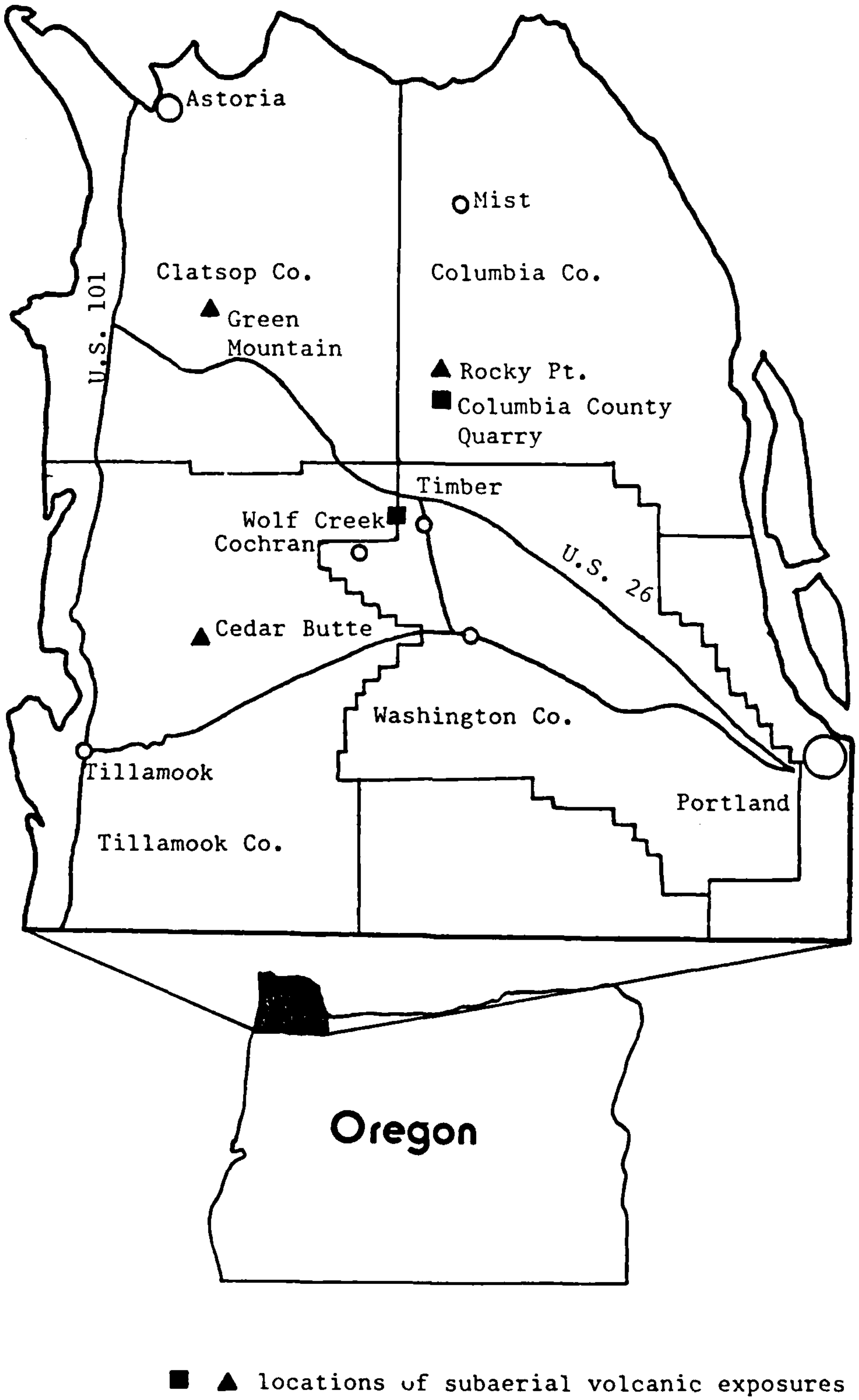


Figure 8. Locations of exposures of subaerial volcanics in northwest Oregon

disagrees with this distinction, citing extreme variability in geochemical values and an insufficient number of samples. It is likely that the chemical difference between these flows results from differentiation in the crust before extrusion, as suggested by Snavely (1987).

Cowlitz Formation:

The strata of the Cowlitz Formation demonstrate a wide range of depositional characteristics, representing a continually dynamic paleoenvironment of deposition. The deposition of the Cowlitz Formation apparently occupied one transgressive-regressive sequence (McKeel 1983, 1984) as determined from a paleobathymetric analysis of foraminifera. Cowlitz strata are thickest in subsurface near Mist, Oregon (Bruer, 1984). Shaw (1986) considers the sediments of the Cowlitz in the Nehalem Basin to form a discontinuous arc surrounding the highlands of Rocky Point.

The most complete petrographic analysis of the Cowlitz Formation was completed by Van Atta (1971). He divided the Cowlitz Formation into three members: a basal siltstone member, a sandstone member, and the Goble Volcanics member. He described the stratigraphic relationships as conglomerate grading laterally "away from the volcanics into volcanic sandstone, which in turn

passes into the siltstone which constitutes the bulk of the lower Cowlitz Formation." Van Atta concludes that the primary structures demonstrated by the sandstone unit suggest a littoral to shallow-water marine environment. The time-dependent variation in depositional environment due to the regressive cycle was also recognized by Van Atta as recorded in the interbedded siltstone and mudstone within the sandstone member. He postulates a dominantly continental provenance for sediments of the Cowlitz Formation.

Timmons (1981), in an examination of Cowlitz lithofacies, identified discontinous lenses of siltstone and mudstone, cross lamination, and low angle even lamination. Reading (1978) considers these characteristics typical of the rapidly fluctuating depositional conditions usually found in a wave-dominated environment. Shaw (1986) describes strata grading laterally east in the Nehalem section as well-sorted conglomerate, interbedded with siltstone, grades into mudstone. East of Mist, the sandstone unit of the Cowlitz Formation (informally named the Clark and Wilson Sandstone) is replaced by coal deposits and inner neritic mudstones.

Storm surge deposits were recognized by Timmons (1981) in the Nehalem Basin. These deposits are identifiable by a large amount of organic debris, trough-

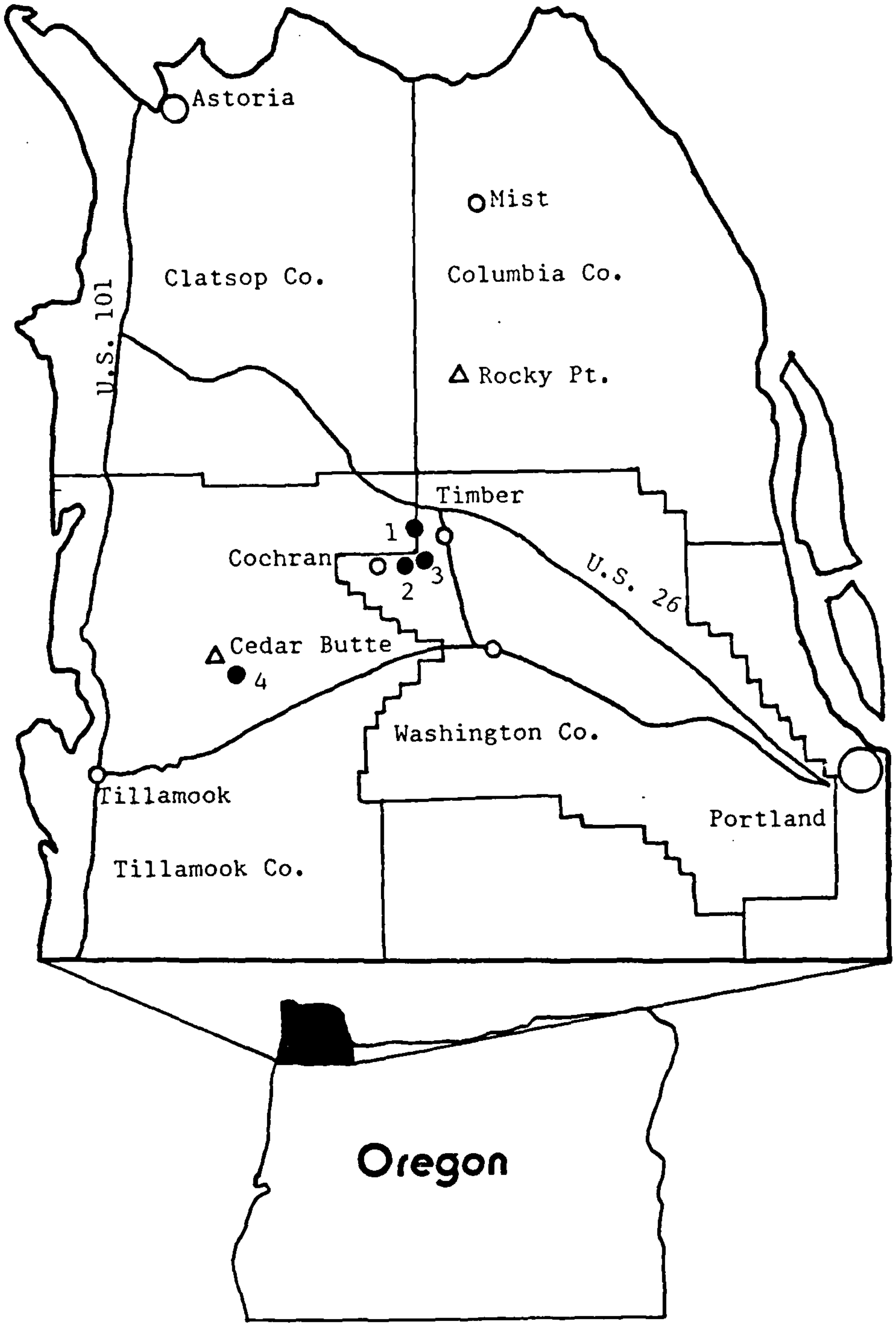
set cross-bedding, and small scale channeling. One channel identified by Timmons produced a 25 cm. thick deposit of coaly material. Examination by the author showed this to be a sub-bituminous coal lens. Lignite laminae occur frequently in the upper portion of the siltstone layer, and the material contains a high percentage of volcanic rock fragments, suggesting a provenance in the paleotopographic highs. The lower mudstone units have been suggested as the source rocks for the Mist Gas Field by Bruer (1980). Paleocurrent analysis of the strata by Timmons (1981) yields a bi-directional paleocurrent ranging from N35 W to N50 W. Timmons considers the primary signs of energetic, nearshore deposition to be: (1) presence of carbonized organic remains; (2) boulder conglomerates; (3) rounded volcanic sandstones with high angle planar cross-bedding; (4) presence of <u>Thalassinoides</u>; and (5) the presence of thick-shelled pelecypods. A conglomerate unit, which Timmons (1981) postulates as a shoreline deposit, is exposed at Stanley Creek: Sec 28, T 5N, R 6W, Cochran Quadrangle, Oregon and along Highway 26: Sec 11, T 4N, R 6W, Timber Quadrangle, Oregon.

Paleontology:

Paleoflora:

The most convincing argument for an emergent section of land extending over a large area is the presence of fossil floral assemblages. Since the land was probably exposed for the period of one transgressive-regressive cycle, the extant flora must have had time to dominate between periods of volcanism. The fact that more floral evidence has not been found is not surprising in view of the limited exposures available in the Coast Range and the dominance of marine deposits. Identification of the flora is complicated by the similarity of the regional conditions to those of strata described by Wolfe (1968) in the Puget Group of southwestern Washington. In a study of fossil flora, Wolfe described 5 new genera and 23 new species. Due to the relative isolation of a flora occupying an island and the lack of described floras from the coastal margin, it is likely that a similar situation is encountered here, with new, undescribed species representing a significant portion of the total specimens.

The clearest example of freshwater terrestrial deposits is an exposure along the Southern Pacific Railroad west of Timber, Oregon (Figure 9). An examination of the outcrop by Warren and Norbisrath (1946) yielded a report of *Aralia* in association with



●1 Wolf Creek assemblage
●2 Cochran assemblage
●3 Wedeburg assemblage
●4 Cedar Butte assemblage

Figure 9. Locations of floral and macrofossil localities

marine fossils. Since Aralia was a generic term for palmate shaped leaves and is no longer in common usage (Manchester, pers. comm.), the author regards this specimen as most likely an occurrence of Platanophyllum. The mention of marine fossils brings into doubt whether the outcrop referred to is, in fact, the same. While mapping the Cowlitz Formation, Jackson (1983) noted the presence of Equisetum, Lastera, Platanophyllum, and palm frond. On the basis of these genera, he postulated a mean annual temperature of 13° C.

Thirteen genera, comprising the Cochran flora, have been collected (Ries, unpub. field notes), and the following have been identified:

Platanophyllum (leaves, wood)
Alnus
Platanus
Quercus
Magnolia
Sabalites
Lastera
Equisetum
Polypodiaceae (fern)

Due to the limited number of genera, physiognomic analysis of this assemblage is not practical. However, some basic conclusions can be drawn from this assemblage. Platanophyllum and Equisetum obviously dominated the depositional environment, comprising close to eighty percent of the total specimens. Sabalites is also represented by numerous specimens. The fact that these broad-leaved genera are represented by so many large,

complete specimens, indicates an extremely low-energy deposition in situ, such as a marsh environment. This conclusion is further supported by the abundant Equisetum rootlets.

A more diverse assemblage is preserved in another Southern Pacific Railroad exposure to the east of the Cochran exposure and stratigraphically above the Cochran Section. Although the poor preservation prevents identification of many of the specimens, enough detail remains for physiognomic analysis under the constraints suggested by Wolfe (1978). The basic premise of this interpretation is that progressively more tropical assemblages are represented by a greater ratio of entire-margin to serrate-margin leaves.

This assemblage is represented by 23 genera (Ries, unpub. field notes), comprising the Wedeburg Flora. The following genera have been identified:

Platanophyllum (2 species)
Sabalites
Equisetum
Lastera
Sequoia
Smilax
Eugeniophyllum

Floristically, this assemblage is similar to that of the Cochran locality, although the assemblage has been transported prior to deposition. The assemblage was apparently deposited in a brackish-water, perhaps even in a lagoonal setting, as indicated by the numerous

specimens of the brackish-water pelecypod _Pitar_, and the single occurrence of the gastropod _Turritella_.

Of the 23 genera represented, 19 are angiosperms and can be used for physiognomic analysis. Of these 19 genera, 13 or 68% are entire-margined and 6, or 32% are serrate margined. According to the leaf index curve compiled by Wolfe (1971), this suggests a mean annual temperature of 20° C., which is considered a subtropical zone.

Farther south and west of the Cochran and Wedeburg assemblages, a flora occurs in the Cedar Butte area in lacustrine shales interbedded with the Wolf Creek Breccia. Although an accurate correlation between strata is not possible, they are approximately contemporaneous.

The Wolf Creek Flora consists of twelve genera of which the following have been identified:

Platanophyllum
Cornus
Ailanthus
Juglans
Pinus
Picea
Chamaecyparis
Poacites
Typha

(Ries, unpub. field notes, Cameron, 1980)

Macrofauna:

Olequah Creek:

The type section of the Cowlitz Formation is exposed

along the Cowlitz River and Olequah Creek in southwestern Washington (Figure 10). Not only is the section along Olequah Creek important because of the irrefutable evidence of freshwater deposition, but diverse assemblages are also preserved from layers adjacent to the freshwater deposits, providing important information on the biostratigraphic transitions.

The first examination of the section was by Weaver (1916a) and his observations remain the most complete and thorough investigation to date. Weaver identified a series of strata in which the depositional environment changed from marine to brackish-water, from brackish-water to freshwater, and then progressed back to brackish-water and finally to marine deposition.

Throughout this succession of strata Weaver identified over 120 macrofossil species. The species of immediate concern to this study are those preserved in the freshwater strata. Weaver describes specimens of Unio transpacifica, Rimella simplex, Turris washingtoniana, and Turritella uvasana. The brackish-water strata identified by Weaver are nearly barren, while the marine strata contain an abundant fauna correlative with the type Tejon molluscan fauna of California.

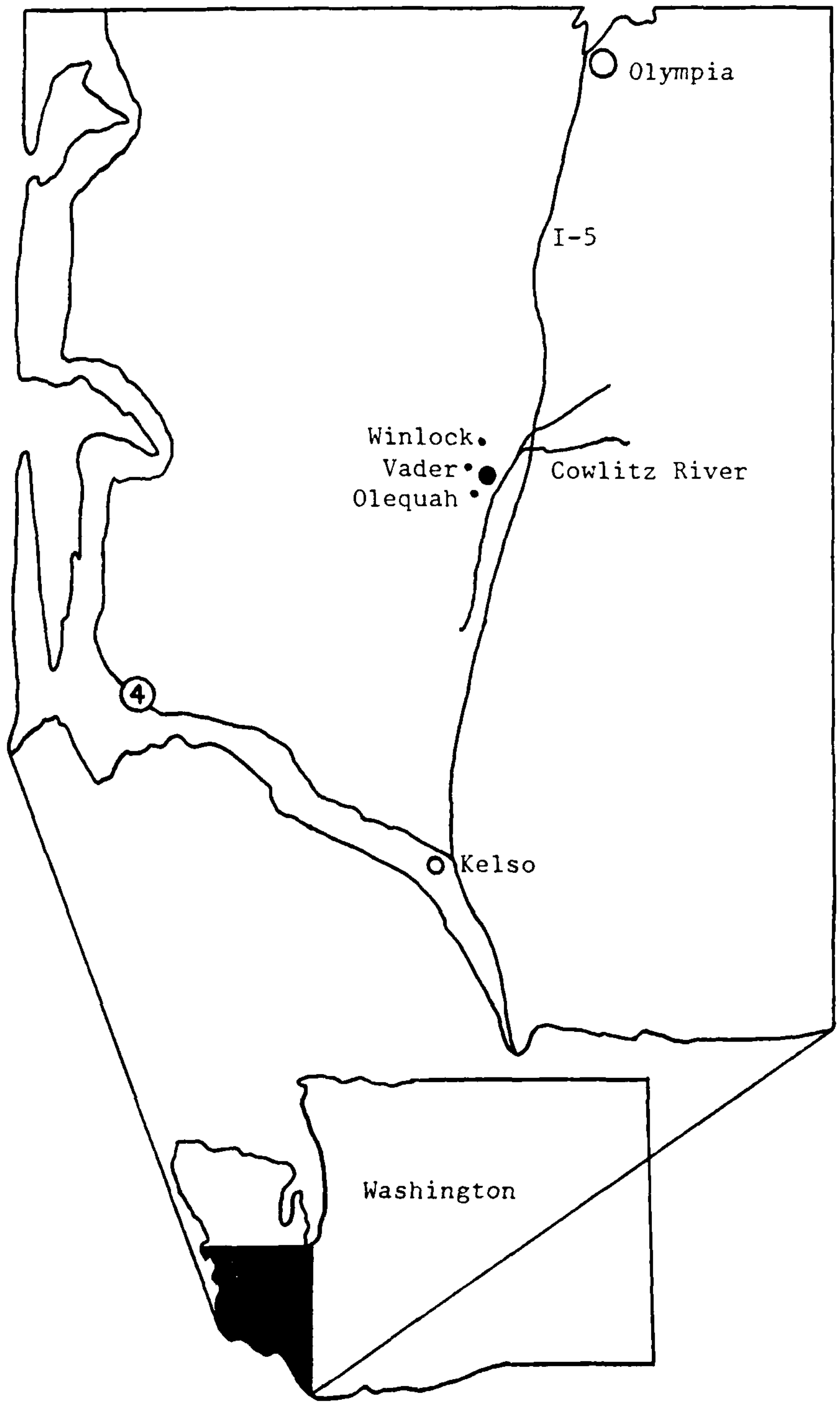


Figure 10. Location of Olequah Creek section in Southwest Washington

Cedar Butte:

Marine macrofossils from the Cedar Butte area are extremely rare, and provide conflicting evidence for depositional environments. Nelson and Shearer (1969) describe the occurrence of an Unio? from the lower submarine breccia unit along the north fork of the Kilchis River (Figure 9). However, Cameron (1980) describes the occurrence of Delectopecten sp.? from the second sedimentary subunit of the breccia. The indefinite nature of these identifications leaves the depositional environment in doubt. Cameron (1980) considers the presence of Glycimeris and Acila in the lowermost siltstone unit indicative of a moderate to deep-water marine depositional environment. However, Orr and Orr (1981) and Nesbitt (1982) consider both Acila and Glycimeris typical of middle neritic to brackish-water facies.

Two specimens of pelecypod were found by the author at the floral locality in the second sedimentary subunit. Both were tentatively identified as Unio, an exclusively freshwater pelecypod (Nesbitt, 1982). Unio is also found in outcrops along Olequah Creek, the type section of Cowlitz Formation in southwestern Washington (Weaver, 1916; Nesbitt, 1982).

Numerous fish scales were found in association with the leaves (Plate V), but only a couple of minor

disassociated bones. The majority of the scales appear to be catostomid, probably Amyzon, also indicating probable freshwater deposition, most likely a lacustrine environment (Cavender, 1968)

Wedeburg:

Another important marine assemblage is associated with the Wedeburg flora near Timber. The depositional setting of this assemblage is almost certainly a shallow brackish-water setting. Two genera of marine fauna have been found by the author: numerous specimens of Pitar sp., also recognized by Jackson (1983), and a single specimen of Turritella. Nesbitt (1982) analyzed the paleoecology of Pitar communities in the Cowlitz Formation of Washington (including one assemblage on Olequah Creek). Due to the complete absence of other pelecypods, this community would typically occupy the inner neritic prodelta slope niche postulated by Nesbitt (1982). The absence of microfossils for the strata (Jackson, 1983) suggest that this community might have occupied a shallow sand bar or sand flat deposit, close to distributary channels, where there was little wave influence.

In a reconstruction of the stratigraphy along this section of the Nehalem River Basin, Shaw (1986) notes the presence of the trace fossils Chondrites, and Helminthoidea in the Nehalem River section. Jackson

(1983) also found specimens of Rosselia-Cylindrichnus, and Thalassinoides. Timmons (1981) considers the presence of Thalassinoides indicative of a nearshore high-energy environment.

Microfauna:

By using foraminifera collected from the Nehalem River section and the Wolf Creek section by Jackson (1983), Shaw (1986), and by the author, it is possible to approximately place the Cochran and Wedeburg floras within the established framework of Pacific Northwest chronostratigraphy (Figure 11), and more importantly, to establish the relation of these strata to the subsurface strata of the Mist Gas Field.

First, it is possible to establish the lowest possible chronological boundary for these strata from the foraminiferal study of Robertson (1972). Robertson conducted microfauna investigations in a portion of the Yamhill Formation which underlies the strata under investigation, and interfingers with the Tillamook Volcanics. Robertson identified 40 species of foraminifera. Of the 40 species, 14 benthonic species are indicative of the Bulimina corrugata zone of Mallory (1959). Seven species are correlative with the P-13 pelagic foraminiferal zone of Berggren (1971). According to Armentrout (1981), this is equivalent to a medial Eocene or middle Narizian foraminiferal stage.

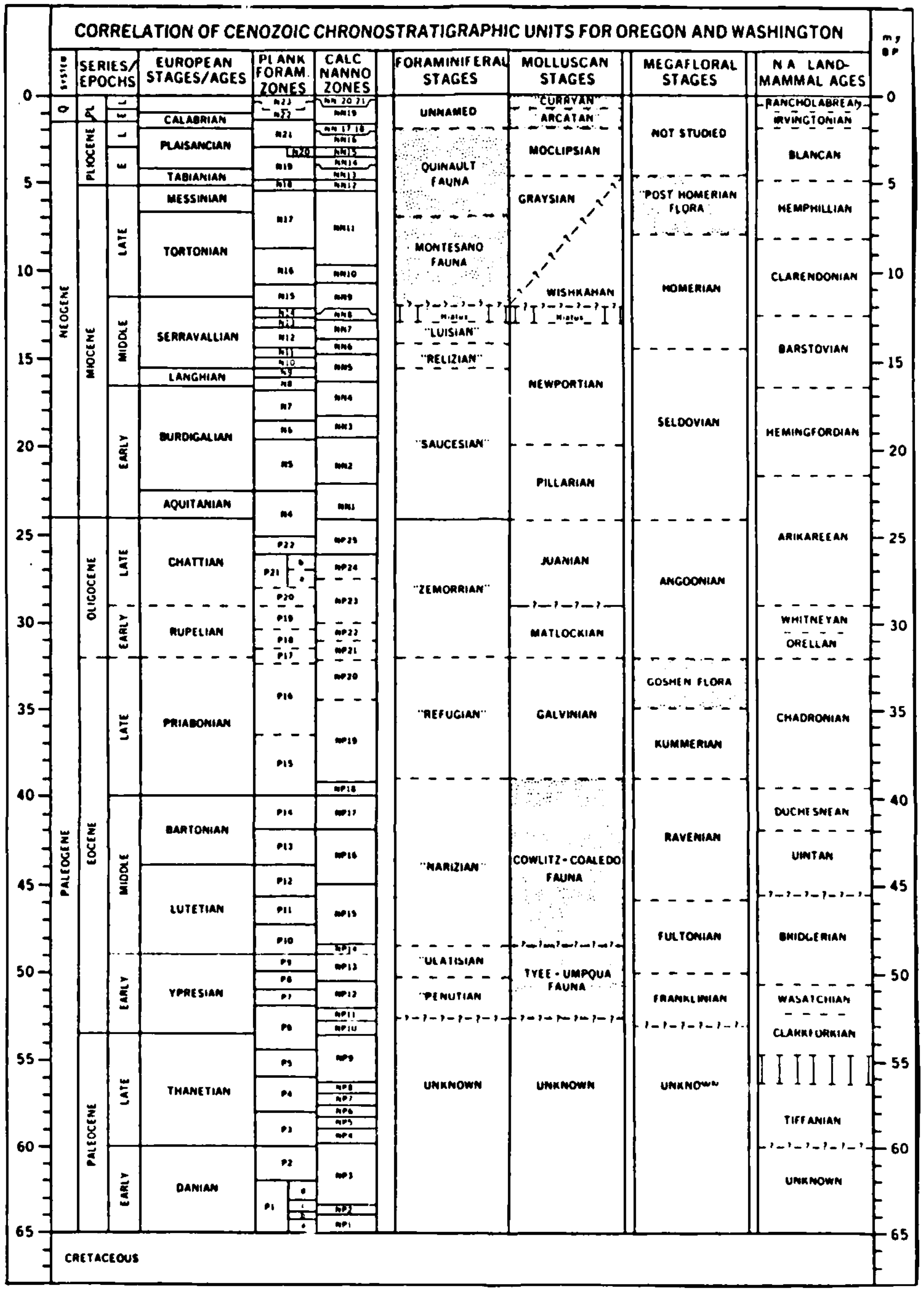


Figure 11. Correlation of Cenezoic chronostratigraphic units

In an examination of the Wolf Creek section of the Cowlitz Formation. Jackson (1983) reported 19 species of foraminifera from 5 localities (see Appendix 1). The following six species:

Bolivina kleinpelli
Gyroidina condoni
Plectofrondicularia searsi
Angulogerina hannai
Cibicides natlandi
Lenticulina welchi

are typical of the Bulimina schencki-Plectofrondicularia jenkinsi zone described by Rau (1981). None of the species are typical of zones above or below this zone. Jackson also reports five species from the Nehalem River section, two of which are characteristic of this zone.

Shaw (1986), in a more intensive examination of this section also reports 19 species, many different than those listed by Jackson. Foraminifera from the lower portion of the section are not sufficiently diagnostic for age correlations. One assemblage from the middle of the section yields nine species, four of which are diagnostic of the B. schencki-P. jenkinsi zone. Specimens collected by the author duplicate those of Jackson and Shaw.

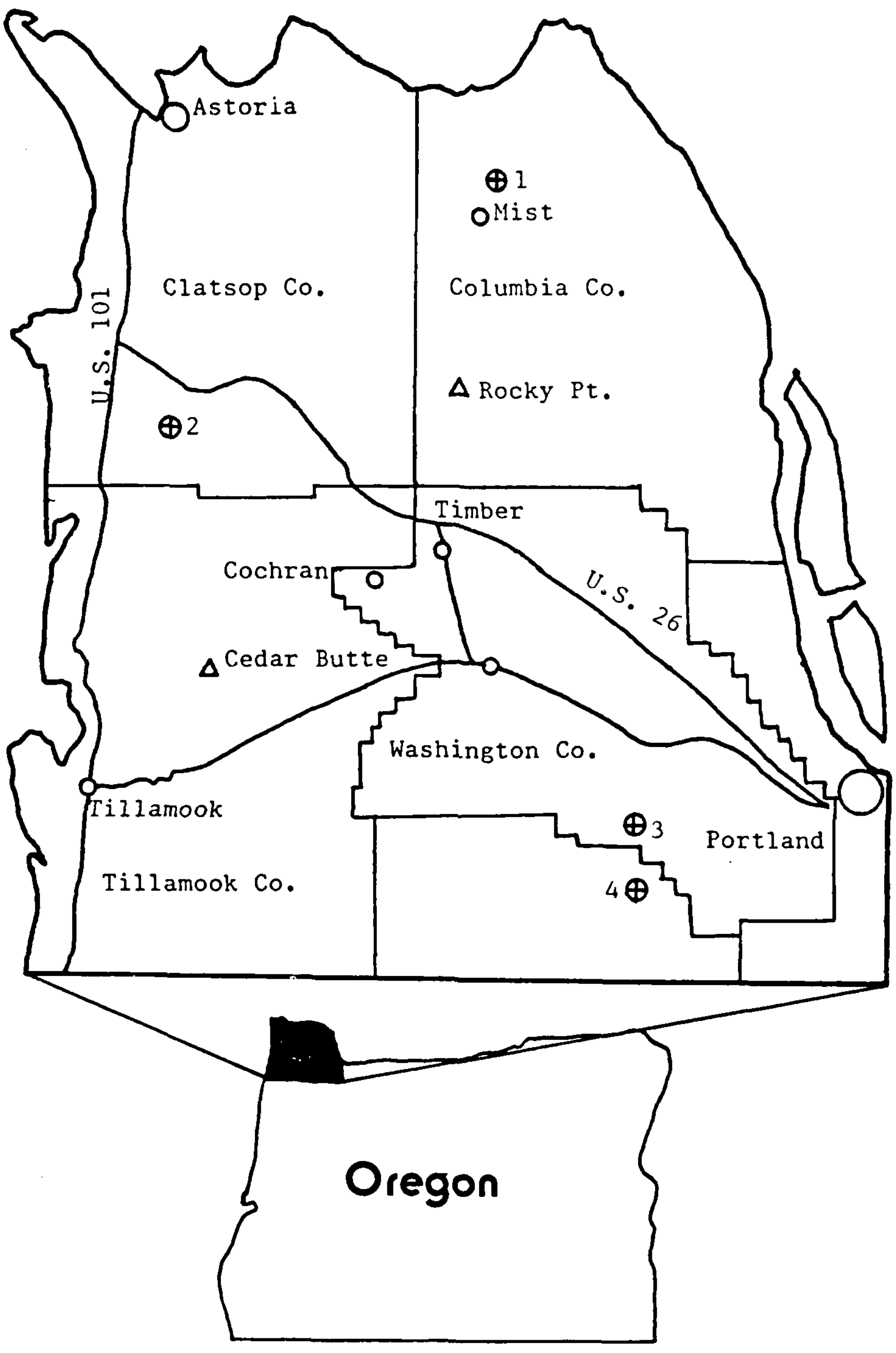
Also important to note in this section is that the top of the section represents the lowest occurrence of Lenticulina texanus, and the highest occurrence of Bathysiphon eocenica.

Well Log Correlations:

For biostratigraphic correlation purposes it is important to correlate these surface exposures with those preserved in the Mist Gas Field to the north. This procedure is complicated by the fact that the sediments to the north are thicker as distance increases away from the island that was formed by the Tillamook Uplands.

In an examination of the stratigraphic occurrence of foraminiferal species, one which appears particularly useful for the purpose of this correlation is Bathysiphon eocenica. This species seems to disappear as water depths become shallower close to the topographic high present at the bottom of the section. The most useful well sections are those that penetrate to lower Narizian strata, ensuring that the upper Narizian section of interest is preserved.

The intrabasin correlations are well documented within the regions of the Mist Gas Field and the Astoria Basin by McKeel (1983,1984, and 1985) and Niem et al (1987). For purposes of this correlation, four well sections will be examined (Figure 12) and correlated with the Nehalem River section of Shaw (1986) and Jackson (1983). These well sections were chosen based on the depth penetrated, quality of biostratigraphic correlations within their basins of origin, and the completeness of the section. The well sections chosen



⊕ location of oil wells

1. Crown-Zellerbach 11-28
2. Texaco Clark and Wilson # 6-1
3. Nahama and Weagant Inc. Klohs no. 1
4. Reichold Bagdanoff no. 23-28

Figure 12. Locations of oil wells used in correlation of sections

for this correlation include the Texaco Clark and Wilson # 6-1, the Nahama and Weagent Inc. Klohs No. 1, the Reichold Bagdanoff No. 23-28, and the Crown-Zellerbach 11-28.

Correlations between these wells were based upon lithology, presence of nonintrusive volcanics, and foraminiferal ages and horizons. A correlation between stratigraphic sections is shown in Figures 13 and 14.

The correlation between sections is obvious at the top of the volcanics in the Crown Zellerbach 11-28 well at 4500 feet, and the top of the volcanics in the Nehalem River section. This boundary is also fairly obvious in the Texaco Clark and Wilson # 6-1 as volcanic rocks, breccias, and sandstones begin at 4500 feet. These units are probably correlative with the volcanics at the base of the Nahama and Weagent Inc. Klohs # 1.

The sections preserved and recovered in these four wells also reflect two regressive stages during the upper Narizian. This occurs in the Nehalem section, and the lower cycle there is apparent at the brackish-water deposits. The freshwater deposits might at first appear to represent this stage, but in fact merely represent an area of land which remained exposed for the entire sequence. The second regressive stage is higher in the unmapped section, but was noted by Jackson near the Cowlitz-Keasey contact in the section. The

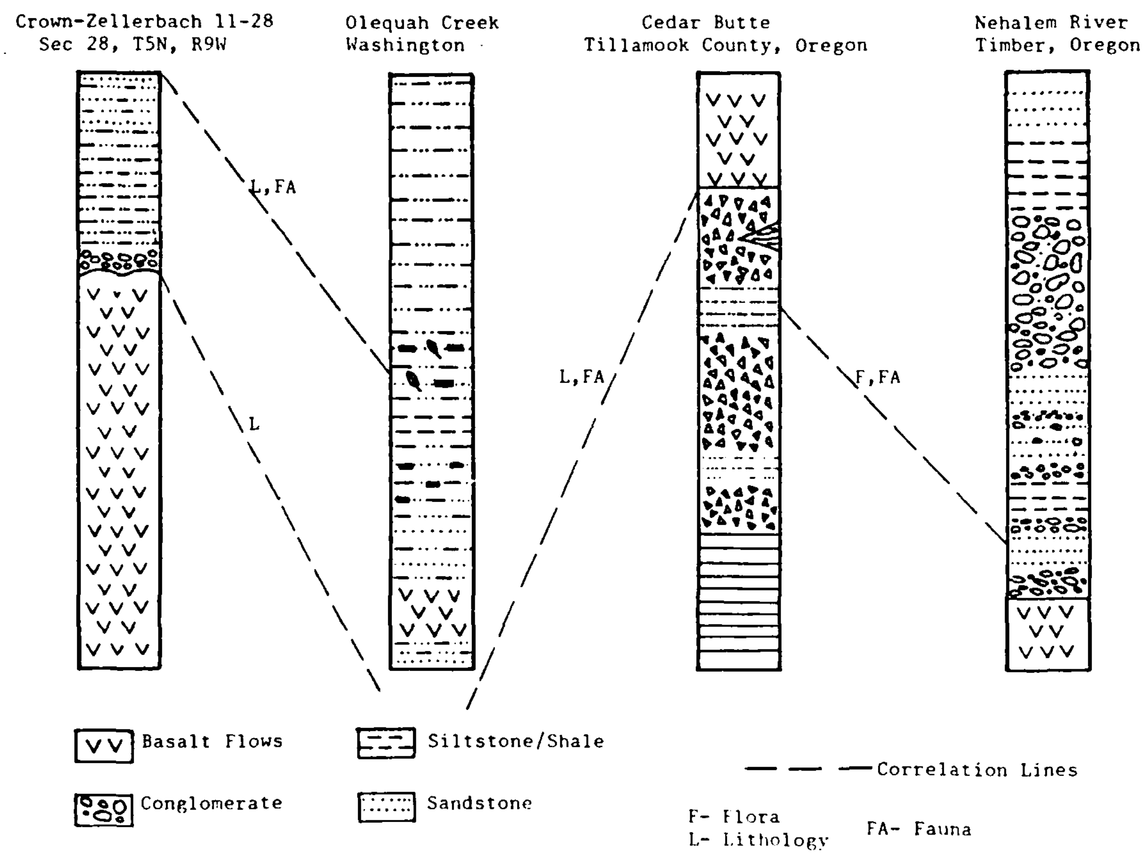
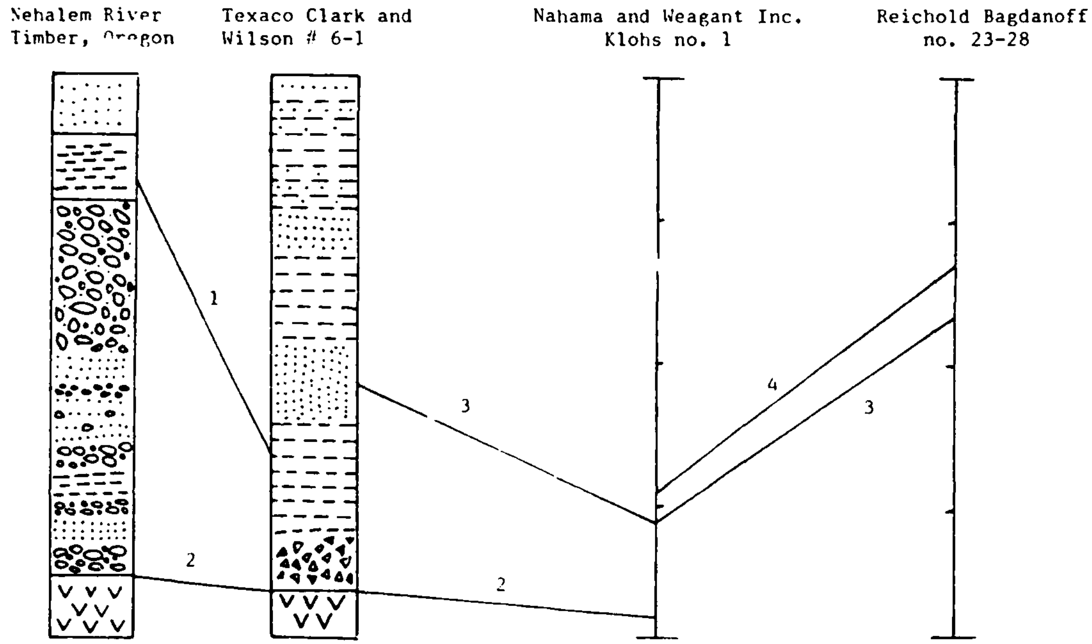


Figure 13 Correlation of stratigraphic sections for interval of study, extracted from Weaver (1916), Cameron (1980), Niem et al (1985), and Shaw (1986).



1. *Cyclammina pacifica* correlation
2. Top of Tillamook Volcanics
3. Correlation of sandstone unit
4. Gilsonite occurrence

Figure 14. Correlation of stratigraphic sections and biostratigraphic and lithologic well logs for interval of study (McKeel 1983, and 1984)

regressions were also documented by Niem, et al. (1985) in the Crown-Zellerbach 11-28 and by McKeel (1983) in the Texaco Clark and Wilson # 6-1. However, the upper regression at the Narizian-Refugian boundary in the Texaco Clark and Wilson # 6-1 is not identified. McKeel (1983) speculates that the regression was between 2052 and 2992 feet and was missed due to incomplete sample recovery. Evidence of these two regressions in the Klohs No. 1 and Reichold Bagdanoff No. 23-28 sections is impossible to identify due to continued close proximity of the site to the topographic high during this part of the section, producing continuous inner neritic and marginal-marine deposition.

A comparison of the paleobathymetric curve compiled by McKeel (1983) from the eastern Nehalem River Basin (Figure 16) with that from the southern Nehalem Basin (present study) (Figure 17) reflects the change in proximity to the island in the basin. The curves obviously reflect the same regressive cycles, with the southern portion of the basin experiencing relatively shallow water deposition near the island.

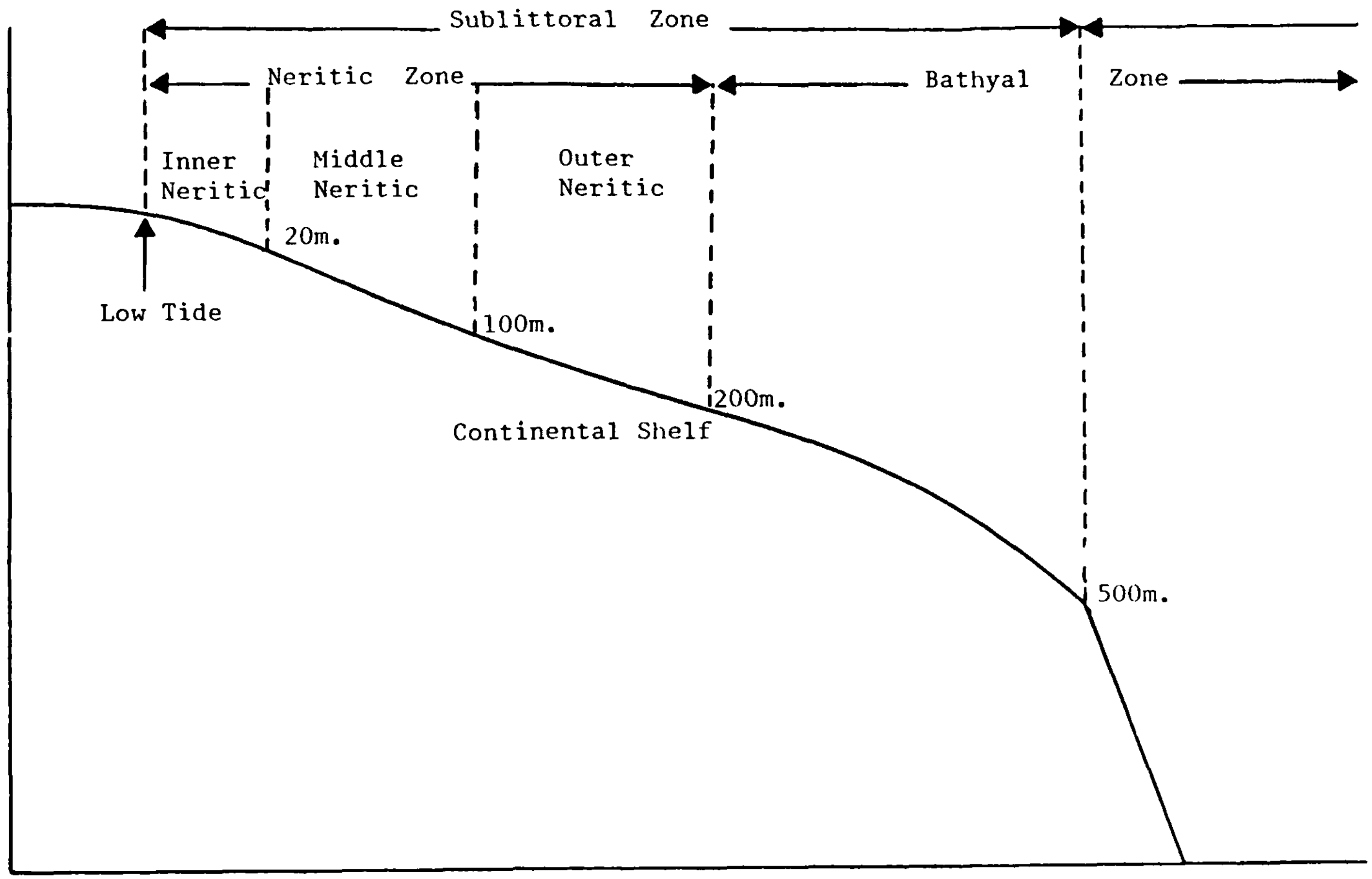


Figure 15. Diagram of marine depth zonation

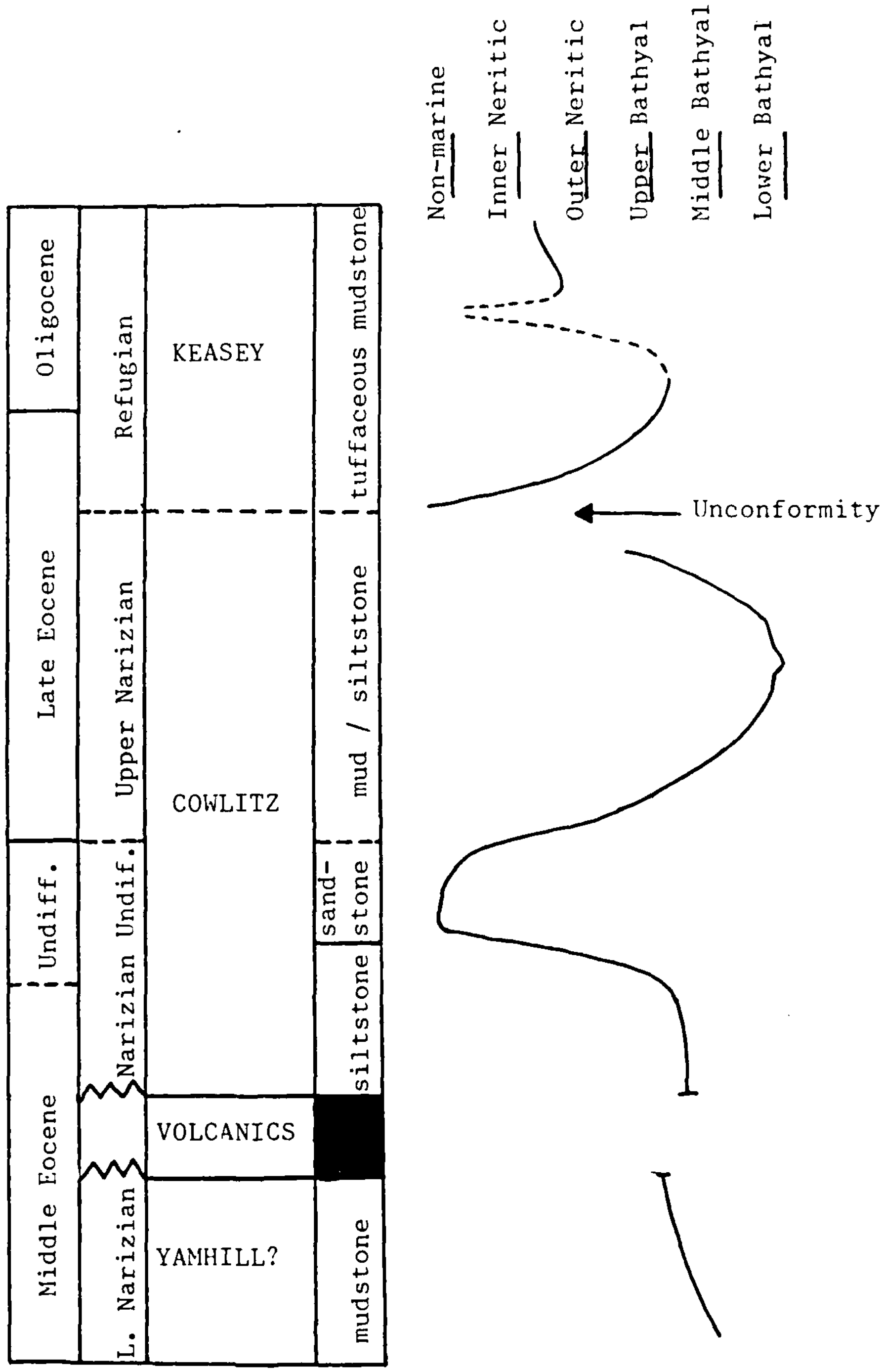


Figure 16. Paleobathymetric curve for eastern Nehalem River Basin after McKeel (1983 and 1984)

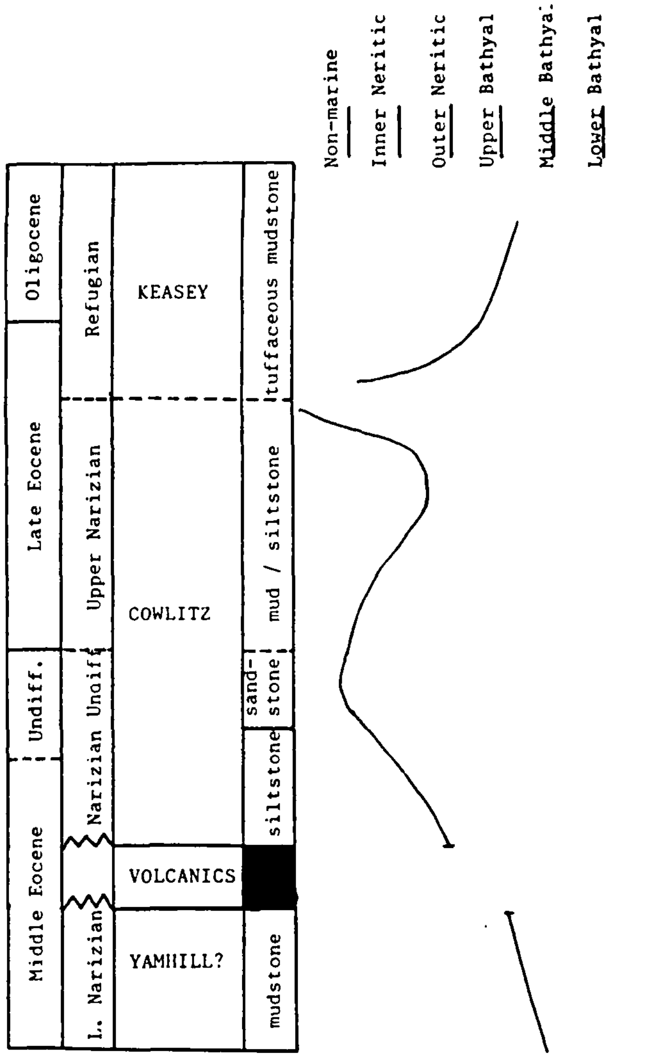


Figure 17. Paleobathymetric curve for the southern Nehalem River Basin (present study)

Stratigraphic Correlations:

Once the interbasin relationships have been established, it is important to place these strata within the established regional geological chronology (Figure 11), by correlation with type assemblages. The Wedeburg assemblage was used for this purpose because it provided the most complete floral record, and the best reference for marine-nonmarine correlations.

Marine fossils place the assemblage definitely within the upper Narizian foraminiferal stage of Mallory (1959). Foraminifera were collected by both Jackson (1983) and Shaw (1986) from the Nehalem River section of the Cowlitz Formation, which contains the Wedeburg assemblage.

Analysis of planktonic foraminifera in a section stratigraphically below the strata exposed in the Nehalem section by Robertson (1972) showed a correlation with the P-13 pelagic foraminiferal zone of Berggren (1969), establishing the oldest possible age for the assemblage.

Molluscs and trace fossils collected by Warren and Norbisrath (1946), Jackson (1983), Shaw (1986), and Ries (unpub. field notes) place the assemblage within the Tejon molluscan stage of California.

Correlation of the planktonic and benthic foraminiferal stages with the molluscan stages as suggested by Armentrout (1981), places the assemblage firmly within the Ravenian floral stage of Wolfe (1981)

and almost certainly within the upper Ravenian. This provides the first definitive marine-nonmarine correlation with a flora of late Ravenian age. The age appears to be about 40-42 million years, which is consistent with the 45 m.y. age proposed for the underlying Tillamook Volcanics by Magill and Cox (1980).

Paleotopography:

An analysis of paleotopography inferred from these assemblages must be carefully made with regard to possible sorting biases occurring during the deposition.

The assemblages encountered in the Cedar Butte tuffaceous sediments are especially suspect. This assemblage consists mainly of Chamaecyparis, Pinus, assorted dicot leaves and fish scales. Nelson and Shearer (1969) and Cameron (1980) both postulated a shallow-water, temperate climate of deposition, based on conifers and deciduous leaves. Although these strata are stratigraphically equivalent to those west of Timber, the preserved flora is significantly different. Axelrod and Bailey (1969) warn against comparisons in regions of topographic diversity when comparing paleofloras. Since over ten miles of lateral distance separates these assemblages, Tertiary topography might very well have been a factor.

Wilson (1980), in a study of Eocene lake-bed deposits of Washington and British Columbia, also suggests the presence of definitive sorting biases correlative with depth and distance from shore. He identifies two separate associations which show a marked contrast. A near-shore shallow-water association is characterized by abundant taxodiaceous leaves or needles, disarticulated Amia and Libotonius and diversity of fossil types. An

off-shore, deep-water association is characterized by articulated catostomids, particulary Amyzon, as well as abundant dicot leaves and few evergreen needles. It is apparent from the consistency of these distributions among Wilson's sample sites that this is a possible explanation for the dominance of the taxodiaceous material at the Cedar Butte locality. This assemblage probably represents a near-shore, shallow-water deposit. A distinct seasonal influence is also recognizable in the laminae, in which summer intervals are immediately identifiable because of the thinner laminae due to reduced sediment input during the summer months. These laminae also contain the majority of the floral remains.

In contrast, the Cochran and Wedeburg floras have a distinctly subtropical appearance. Since the Cochran locality is most likely a stream deposit and the Wedeburg locality is an estuarine or lagoonal environment, the assemblages preserved most likely reflect the true extant flora occupying a low level coastal swamp on the island margin. The Cedar Butte lacustrine assemblage is possibly of higher altitude deposition, making the assemblage dependent on both the altitude of deposition and the distance from shore.

The interpretation of a low-level coastal swamp backed by higher altitude uplands is consistent with an independent palynological examination made by Hopkins

(1967) of mainland deposits in the Coos Bay area of southwestern Oregon. He proposed a basin of deposition surrounded by a low coastal plain backed by highlands, with a lower relief than at present. This is also supported by Dott's (1966) interpretation of the local geology. He proposed a low, swampy subtropical coastal plain backed by forested uplands and volcanoes. Minor volcanic islands were also postulated along the northern Oregon Coast.

Hopkins (1967) also provided a modern analogy for the coastal plain-uplands model. The west side of the island of Luzon in the Phillipines has a sea-level plain dominated by ferns, palm, and bananas. Within a mile inland, mountain elevations reach 6500 feet. Altitude zonation in the flora occurs progressively, eventually reaching zones of temperate forms, including conifers.

Although the paleotopography appears relatively easy to reconstruct with this data, interpreting the lateral extent of this island body is more complex.

Paleogeographic Model: Modifications

After examining evidence which suggests emergent paleotopographic highs in the Eocene basin, it is obvious that the paleogeographic models of Snavely and Wagner (1963) and Dott (1966) which were discussed earlier can be revised.

First, although not accounted for in the model of Snavely and Wagner (1963), it is obvious from the freshwater deposits exposed in Olequah Creek, Washington that an area of land was exposed in this region. Although it is possible that this represents the edge of a prograding Eocene coastline, the magnitude of progradation necessary for this to occur makes it improbable. Therefore, these deposits probably represent an isolated island.

By examining these strata in a paleobathymetric context for this area, one can clearly see the existence of a regressive cycle reflected in the faunal successions. However, this cycle does not coincide with that of the Nehalem Basin in northwestern Oregon. The unconformity existing at the Narizian-Refugian boundary in northwestern Oregon is absent in the Olequah Creek section and both regressive cycles identified in Olequah Creek occur considerably lower in the section than do the regressions in northwest Oregon.

Because of the significant differences observed

between this section and those in northwest Oregon, it is probable that the region in southwestern Washington occupied a separate terrane fragment and was subjected to independent tectonic forces. This was also suggested by Magill and Cox (1980). This would render any attempted correlations with northwestern Oregon useless. Therefore, for purposes of this model, an island is suggested for this region of southwest Washington, and the model concentrates on attaining higher resolution reconstruction of conditions in northwest Oregon during this time period.

Northwestern Oregon is more complex when reconstructing paleogeography. Although much of the evidence is preserved in the subsurface, it is possible to reconstruct the presence of at least three distinct island bodies north of 45° Latitude in northwestern Oregon. The first island occupied an area which included Goble, Oregon. The extrusive center was probably to the north, extending above the present day Columbia River. The western island margin is represented today in the subsurface where the Clark and Wilson Sandstone grades into lignite and coal layers. The eastern margin is hidden in the subsuface.

The second and largest island is represented by the largest subaerial exposure of the Tillamook Volcanics. The eastern margin is represented by the proposed

shoreline deposits occurring between Timber and Cochran, Oregon. The northern margin of this island is indeterminate since the interpretation in the subsurface is complicated by the presence of subaerial deposition from a third island.

Although no direct evidence for the third island is exposed on the surface, it is evident in the subsurface that large sections of the Narizian are missing in several wells, suggesting a hiatus in deposition. From the orientation of the wells, it appears that subaerial exposure had a northwest-southeast axis. The proposed modifications to the paleogeographic model of Dott (1966) are shown in Figure 18.

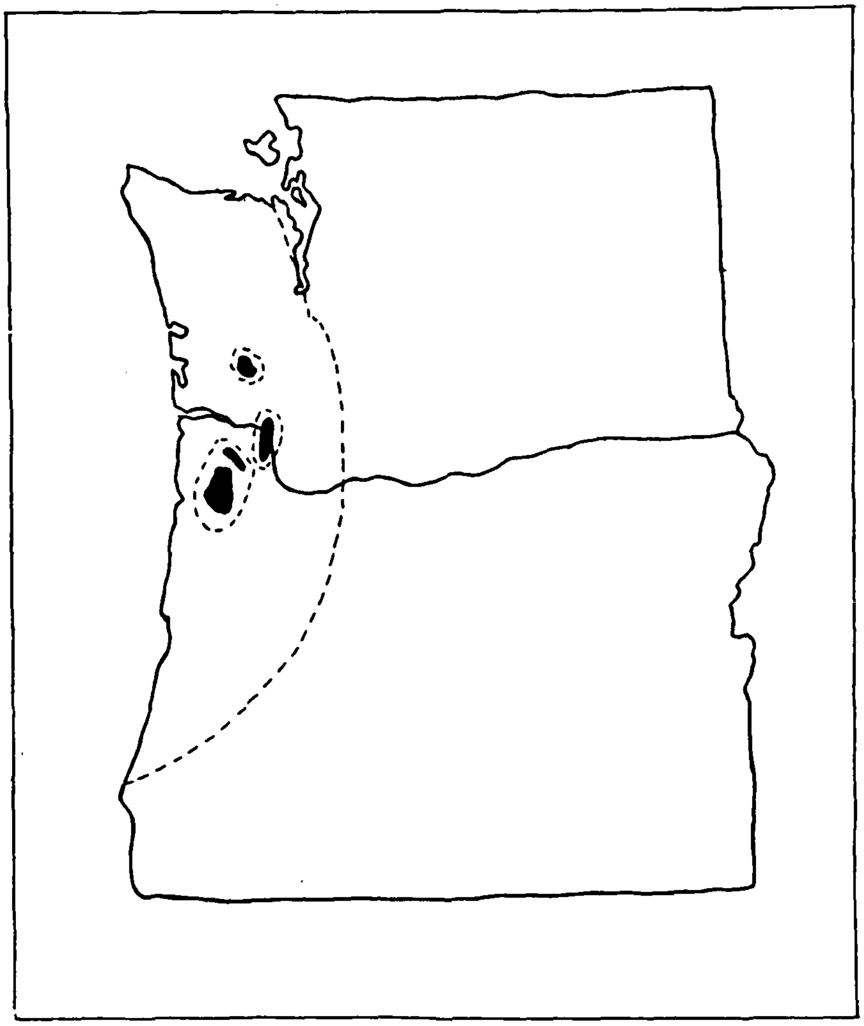


Figure 18. Modification of Dott's (1966) model for the late Eocene paleogeography of western Oregon and Washington

Depositional Model:

Several depositional models have been proposed for the Cowlitz Formation in the past in an attempt to reconstruct the depositional environment of the Clark and Wilson Sandstone in the Mist Gas Field. These models have included a deep-channel model suggested by Bruer (1980), an outer neritic shelf model suggested by Jackson (1983), a deltaic model suggested by Armentrout (1981) and an upper bathyal model suggested by Shaw (1986).

Significant complexities arise from the presence of islands in a basin when a depositional model is considered. The various sections of this paper have discussed the lithology and paleontology of the area. The trend of volcanic strata in the subsurface as well as paleocurrents reconstructed from surface exposures suggest an influx of ocean water from the northwest. The continental provenance of much of the sediment suggests a sediment source to the east. Conglomerate exposures probably represent the coastline of islands in the basin, fringed by lagoonal and brackish-water sandstones. Mudstones and siltstones in the deeper portion of the basin were deposited in middle neritic to upper bathyal depths. A proposed depositional model is shown in Figure 19. No quantitative determination of paleobathymetry is made in the model due to a conflict between bathymetric reconstructions based on molluscan

fauna and those based on foraminifera.

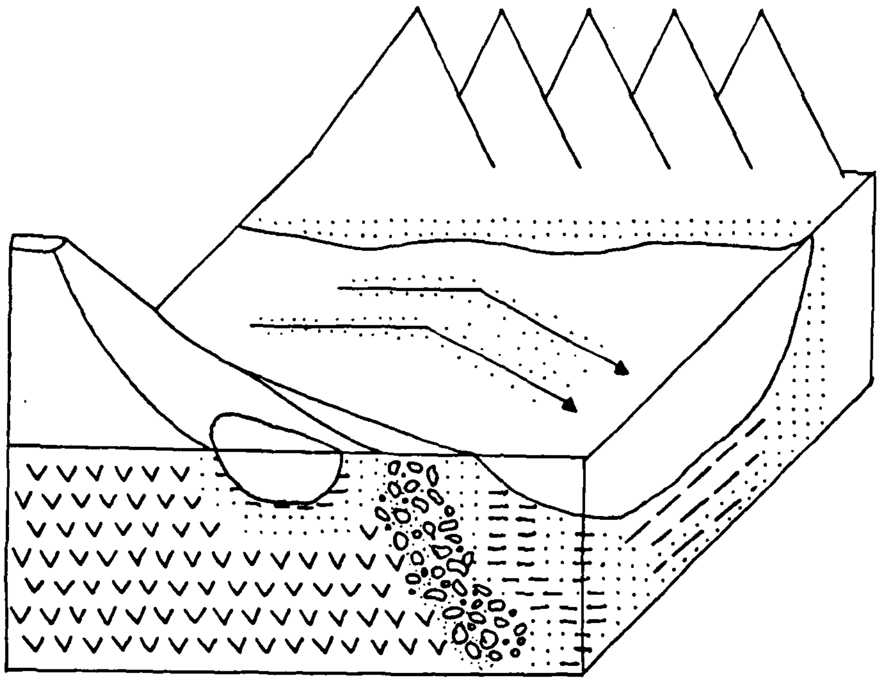


Figure 19. Suggested depositional model for the late Eocene Nehalem River Basin. Current Flow is to the south.

Conclusion:

Although geologic investigations in northwestern Oregon are complicated by a lack of exposures, this investigation has been able to produce significant new information about the climate and geography of the depositional basin during the late Eocene about 40 million years ago.

Northwestern Oregon contained at least three separate islands, each an individual eruptive center. These islands probably formed as part of a seamount chain during rifting of the Kula and Farallon plates, and were accreted onto the continent. Although much of the volcanism was subaerial, the bulk of the sediments in the basin were continentally derived with a probable provenance to the east.

The islands consisted of sea-level coastal swamps dominated by *Sabalites* and *Platanophyllum* backed by higher altitude uplands dominated by *Pinus*, *Picea*, and *Chamaecyparis*. Brackish-water lagoonal depositional environments occupied the margins of these islands. Paleobathymetric profiles of the late Eocene show two regressive cycles. These most likely reflect tectonically controlled subsidence and emergence during the subduction of the Farallon Plate beneath the North American Plate. This eventually resulted in the subsidence of the entire basin and the deposition of the

Oligocene Keasey Formation.

Further work in this area should concentrate on the unidentified species of flora since several most likely reflect new, undescribed species. An attempt should be made to resolve the conflict in paleobathymetric analysis encountered between molluscs and foraminifera. Finally, the area in the subsurface to the east of Mist should be examined in detail, perhaps using seismic profiles, in order to determine whether a fluvial source for the sediments was present. This might resolve questions concerning a depositional model for the Clark and Wilson sandstone in the Mist Gas Field.

Acknowlegements:

There are three people that I especially want to thank for their help with this research: my advisor Dr. Doug Edsall for offering suggestions throughout the year, Dr. Scott Wing of the Smithsonian Institution for his help describing the fossil floras, and most especially my brother Brian, without whom I would not have completed 6 months of field work in 3 weeks.

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Appendix I

Floral Localities:

Cedar Butte: SE 1/4, NW 1/4, Sec. 14, T1N, R8W Enright Quadrangle, northwest Oregon

Wedeburg: SW 1/4, NW 1/4, Sec. 32, T3N, R5W Timber Quadrangle, northwestern Oregon

Cochran: SW 1/4, SE 1/4, Sec. 25, T3N, R6W Cochran Quadrangle, northwestern Oregon

Faunal Localities:

Cedar Butte: SE 1/4, NW 1/4, Sec. 14, T1N, R8W Enright Quadrangle, northwestern Oregon

Reeher Park: SW 1/4, NW 1/4, Sec. 32, T3N, R5W Timber Quadrangle, northwestern Oregon

Olequah Creek: SW 1/4, Sec. 20, T11N, R2W Lewis County, Washington

Nehalem Section: SE 1/4, NE 1/4, Sec.28, T3N, R5W, Timber Quadrangle northwestern Oregon

Wolf Creek Section: SE 1/4, NW 1/4, NW 1/4, Sec. 5, T3N, R5W, Timber Quadrangle, northwestern Oregon

Columbia County Quarry: Sec. 22, T4N, R5W Vernonia Quadrangle northwestern Oregon

PLATE 1

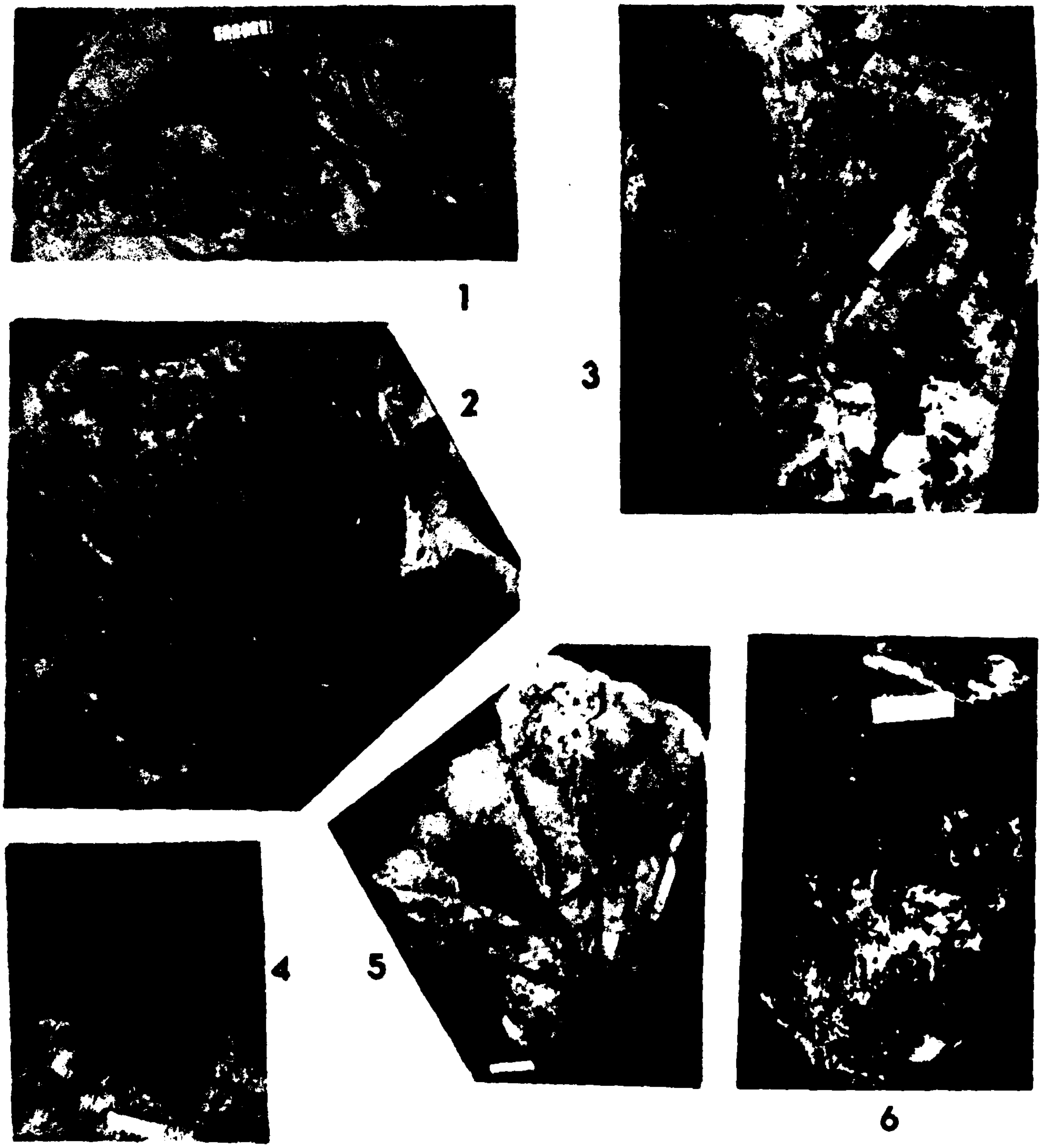
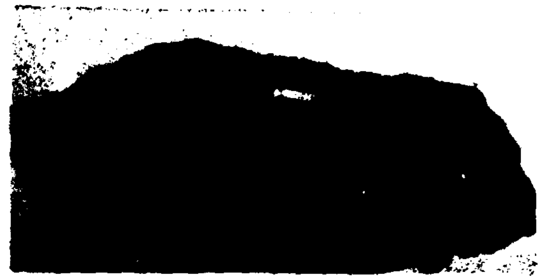


Plate II (Cochran Flora)

1. Polypodiaceae (fern)
2. Unknown reed
3. Platanophyllum Augustiloba
4. Unknown
5. Quercus
6. Unknown

PLATE II

1



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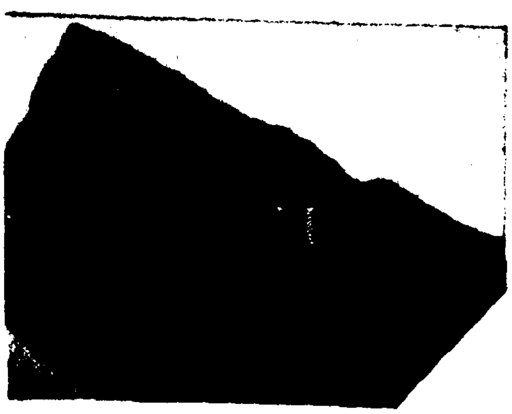

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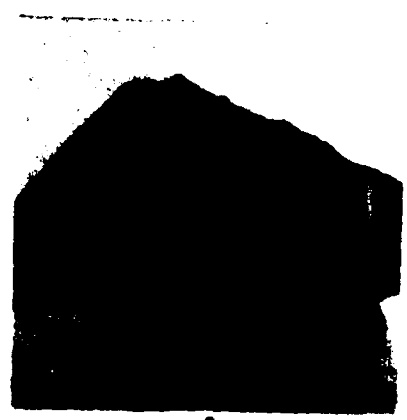

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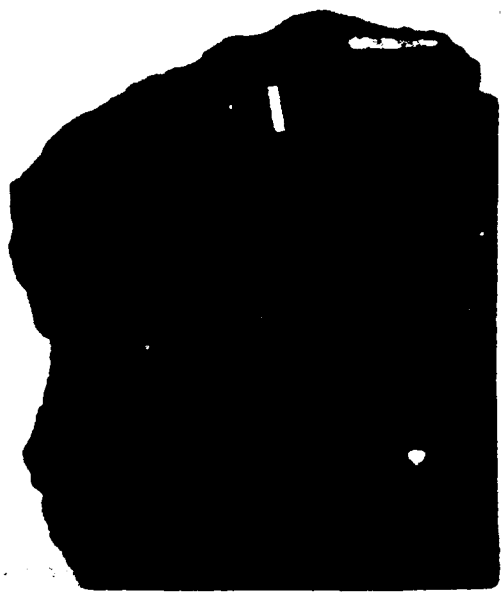
Plate III (Wedeburg Flora)

1. *Laurophyllum*
2-5. Unknown

PLATE III



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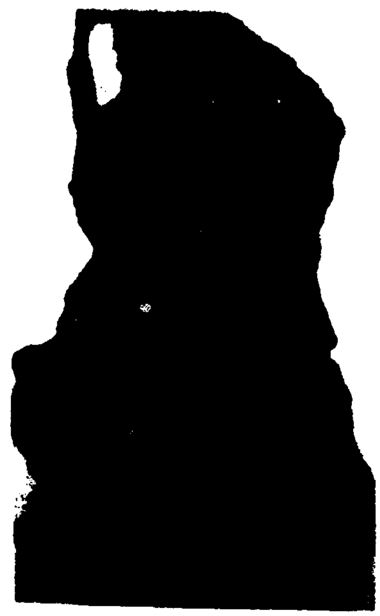

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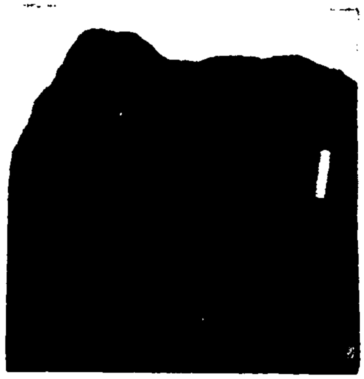

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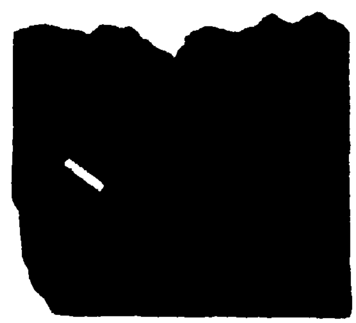

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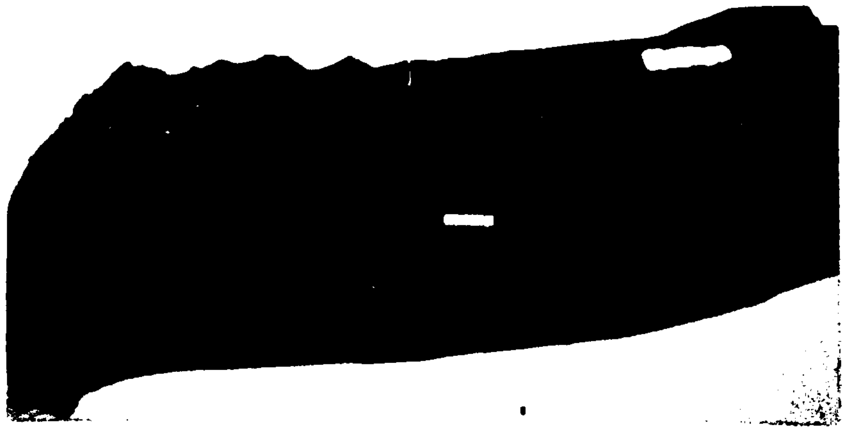
5

<u>Plate IV</u> (Wolf Creek Flora)

1. *Pinus*
2. *Poacites*
3. *Chamaecyparis* cone
4. *Typha*

PLATE IV



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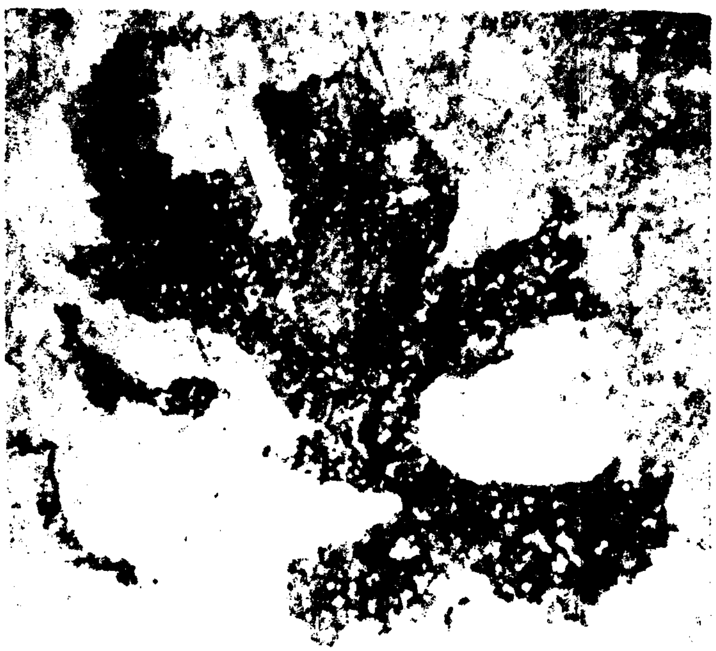

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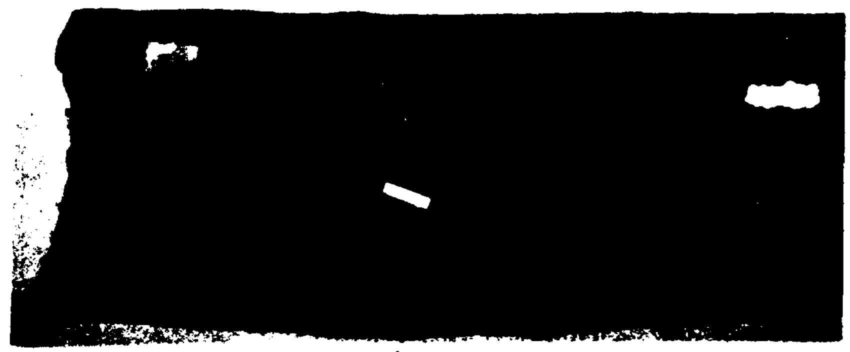

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Plate V (Cedar Butte)

1. Unknown (1.1X)
2. hiodontid scale (1.1X)
3. *Hiodon* (1.0)
4. *Amyzon* (1.1X)
5. Unknown (1.1X)
6. *Amyzon* (1.1X)
7. *Amyzon* scales (0.9X)

Plate V

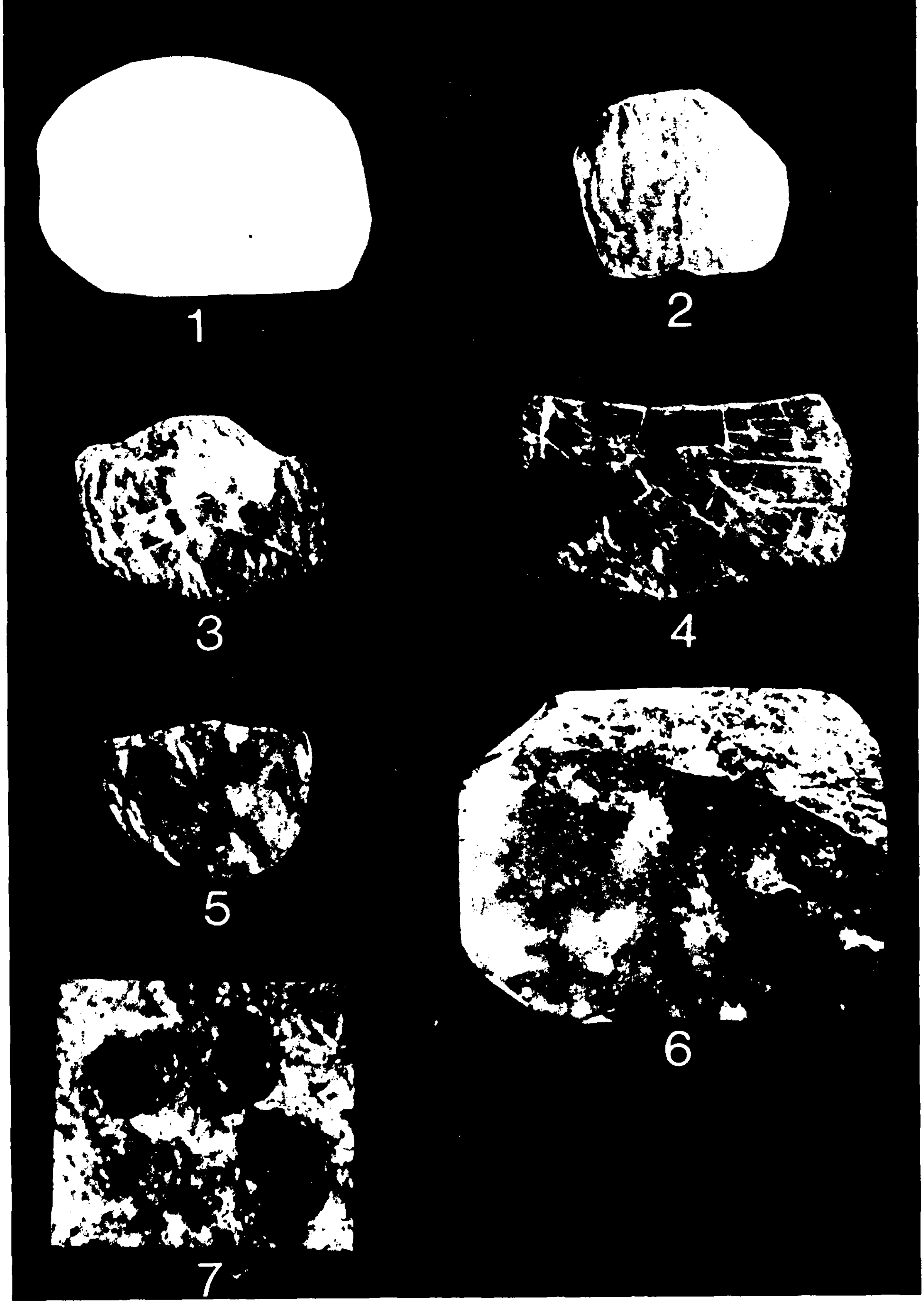
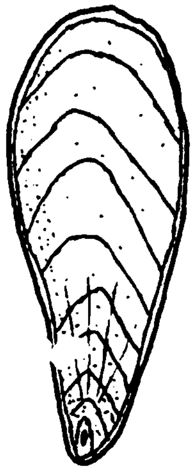


Plate VI (foraminifera)

1. Plectofrondicularia searsi
2. Cibicides natlandi
3. Bathysiphon eocenica
4. Bulimina schenki
5. Lenticulina welchi

Plate VI



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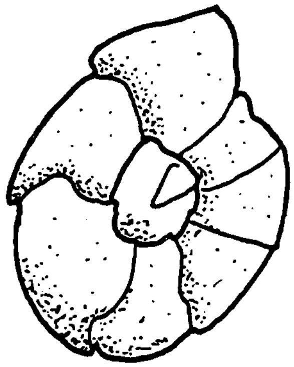

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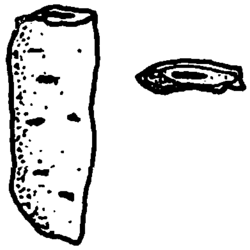

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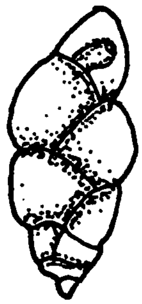

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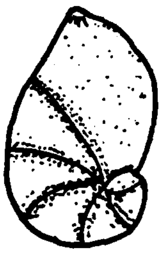

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